Compressed Air

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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SAWING WITH A PNEUMATIC HAMMER.

Compressed Air.

OR

THE COMPRESSED AIR MAGAZINE.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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Compressed air is the safest of all powers. No other power or means of transmitting power compares with it in safety. This quality is one of great importance and is, we think, underestimated by those who advocate the use of compressed air. We have been carrying on for some months a series of editorials in this paper reciting cases where explosions have occurred in compressed air passages, and have been in a general way discussing the subject. It may have surprised some of our readers to hear so much about explosions in compressed air, and in fact we have been asked the question why we dwell so much upon a subject which only furnishes ammunition to electrical engineers. Our only answer is that compressed air can stand this sort of thing. Its freedom from explosions and its extreme safety in use, are so well known and so far beyond dispute when comparing air with electric or any other power, that we are encouraged at all times to search out cases where air has been shown to be unsafe, running them down by getting at all the facts, and pointing out where the fault lies so that such things may be stopped. Nothing of any great importance in industrial use is absolutely safe: Railway trains meet with accidents, bridges sometimes fall, buildings collapse, boilers explode, and yet no one thinks of abandoning the use of these things because they are unsafe. Compared with the number of buildings that fall, accidents of this kind are rare, and taking into consideration the number of boilers which are in use explosions are not serious, and when we consider the large number of compressed air installations using air, varying in pressure from 1 lb. to 3,000 lbs. to the square inch, an explosion is a rare occurrence. Every passenger train and a good many freight trains on every railroad of magnitude in the world is equipped with air compressors and storage tanks containing compressed air at considerable pressures, yet who ever heard of an air explosion on a railroad train? Most of the railroad shops and most of the machine shops in America have air plants. Nearly every mine of magnitude, where the ore is hard and where mining operations are carried on on a large scale, is equipped with a compressed air plant, and yet how many of us have heard of explosions there? A large number of compressed air installations are in use as permanent plants lifting water from driven wells: Caissons are commonly used for excavations under water: Tunnels through hard and soft ground invariably use compressed air: Street cars have been in use more than ten years in France, and during recent years in New York, with air as the motive power: Foundries are now equipped with air compressing plants, which are

considered just as essential to their existence as the foundry crane: Coal mining machines, though in some cases propelled by electricity, chiefly use air: Quarries are equipped with air plants.: Ships are provided with air compressors for refrigerating purposes: Air is used to some extent for lifting sewage, and yet how seldom do we hear of explosions or accidents due to the use of compressed air. The reason for this is very plain. Air is a harmless elastic fluid, non-combustible, healthy, and it is the most widely distributed of all substances. We simply compress it and hold it in a condition of confinement, and must provide a vessel strong enough to overcome its elasticity. Unlike steam air has no reserved force when in confinement. The destructive effect of a boiler explosion is mainly due to the sudden conversion into steam of large volumes of superheated water, held in a condition of water by the pressure of steam on top of it. Here we have a reserve force. With air when once a vent occurs the pressure falls very rapidly and the strain is soon relieved. This rapid fall of pressure is due to two things, expansion of the air from a smaller space into a larger one, and a rapid reduction in the volume of this air, due to shrinkage in expansion by cooling. Liquid air is produced by expanding compressed air down to atmospheric pressure, the intense cold being utilized to liquefy volumes of compressed air. This cooling effect takes place when air is expanded, and the rapid shrinkage of volume follows.

Now, as a matter of fact, no accidents occur in the use of compressed air that may not be traced to explosions through the ignition of oil or inflammable substances which are used with the air. If we throw kerosene oil into the inlet valve of a compressor, we are likely to have an explosion because this oil may meet with a temperature which is higher than its flashing point, and so with certain low grades of lubricating oils; but the air itself is perfectly safe, it being merely necessary to confine it in a receiver or pipe which is strong enough to hold it. This is not a serious problem, and in the case of air the factor of safety is not nearly so great as where steam, water, gas or other substances are similarly confined, because air does not corrode the vessel, its temperature is not changed, nor is there any liability of internal destructive action taking place, hence, it will be generally admitted that air, except through the course of compression, is as near the point of absolute safety as anything of this class can be. The elements of danger are therefore confined to the compressor, or, more properly speaking, to the compressing plant, and it is to this subject that we have been devoting our attention. Should some one discover a lubricant for air compressor cylinders which is not composed of a carbon, there would be no further occasion for discussion on this subject. It is simply because of the elements of uncertainty attending the use of oil that explosions in compressed air are made possible, and it is also because of ignorance as to the causes of these explosions and the carelessness on the part of the engineers that we hear anything about the subject.

Engineers get in the habit of feeding oil to the air cylinders as they would to steam cylinders, and compressed air generating plants are sometimes run so carelessly that proper attention to the causes producing explosions is not given. As the use of compressed air grows it becomes better understood, and the more we understand it the more we are convinced of its great safety and cleanness. Men are not afraid of a machine run by compressed air. There is no dread in their mind to upset their nerves. We are told that this feeling of dread exists among men handling electric machines,

especially in mines. The electric current is a mysterious thing. It gives a shock, and it is not an uncommon thing for persons to read that electric shocks have produced death. It is known that in two States in America electric execution has replaced hanging, and all these things combine to add to the terrors of this great and mysterious form of nature's energy. Fires are becoming more frequent in large cities. Insurance statistics point to the serious effect which electricity has had in producing fires. Electrolysis is a destructive agent, directly traceable to the large use of electric power in cities, and all these things combine to make more plain the absolute simplicity and safety of pneumatic power.

It is perfectly practicable to heat compressed air before it passes into the motor cylinders, by means of electric currents, and that without the slightest danger. It may be done either by forming a resistance coil in the usual way, in the path of the air, or by wrapping the pipe with a conductor through which a current of electricity is allowed to pass. The conductor must in each case be allowed to attain a fairly high temperature, but it need not be exposed, nor need the temperature be such as to be dangerous, in case of the presence of an explosive gaseous mixture.

Compressed Oxygen is now strongly recommended as an almost certain remedy for asphyxiation produced by bad air in mines. A chamber is provided of sufficient size filled with the gas under pressure of 30 pounds. Into this the unconscious victim is placed. Asphyxiated animals so nearly dead that heart action has almost ceased are very quickly revived. Of course, when the patient is only partially affected and the lungs are still moving, the oxygen may be supplied direct from small portable cylinders by tubes leading to the mouth; Such cylinders properly charged with the gas may now be obtained in Denver.

We show on the cover of this issue a rather novel application of the pneumatic hammer. On the end of the piston rod of the machine is placed a saw blade which is reciprocated rapidly, approximately to 1,000 strokes per minute, and in this way a pneumatic saw of very handy construction and rapid work is made available. Here is a portable hand

A PNEUMATIC HAMMER-SAW.

saw, which may be placed in any position and which, without exertion on the part of the operator, is capable of doing very rapid and economical work. This saw can be operated by a boy when used for common work. It should be useful in pattern shops, for cabinet work and for wood carving. We have been informed that this machine is in practical operation in a packing house in Chicago, and that it is used there for the purpose of sawing ham bones.

Pumping by Compressed Air.*

By E. A. Rix.

My object in this paper is not so much to enter into an elaborate description of the various methods of compressed air pumping, as to touch on points which seem to have been heretofore neglected by those who have written on the subject, to suggest some new methods and to encourage, if possible, in the building of pumping machinery, to design something specially adapted for the use of compressed air.

Compressed air has been handicapped from the very beginning in the matter of pumping, because it has been used with stock pumps which have been designed in general for boiler feeding and tank purposes, and no particular regard has been paid to the matter of cylinder proportions and appropriate pressures. Compressed air users in the same manner have been obliged to utilize old steam motors of all kinds, the general assumption being that steam motors are equally adapted for the use of compressed air. I will plead guilty to having committed this error on many occasions, and the remarkably poor efficiencies which I have obtained have led me to investigate the matter and to become a firm advocate for the designing of special motors for compressed air machinery. Great attention is paid to the designing of motors for the use of steam, even to the very smallest detail, and yet compressed air, which is almost doubly as expensive as steam to produce, has been compelled to take any misfit for its use, and it has been condemned right and left for lack of economy, and has had a difficult time to maintain its proper existence in the face of the results it has produced in many cases with motors which were designed for something entirely different.

Those who are informed on the subject are perfectly well aware that steam and compressed air, while following in general the laws of perfect gases, are not similar enough in their phenomena to be used in the same motor, the general difference being that for similar terminal pressures the points of cut off are different. Air, also, does not condense, which permits unlimited multiple reheating.

There has been sufficient development made in the line of air compressors, so that now the attention of manufacturers should be turned to the constructing of economical air motors; and among the first to inaugurate this reform should be the pump builders. for pumps, as ordinarily furnished for compressed air, have the poorest economy of any compressed air machinery, not even excepting a rock drill.

It is not necessary to revolutionize shop methods nor to carry an expensive stock of specially designed pumps in order to accomplish the results desired. It seems to me that merely pointing out to an intelligent customer the fact that his pocket will be vastly benefited by having a pump specially constructed for his work will be a great help at the moment, and as soon as it becomes generally known that great advantages are to be gained thereby, many people will abandon the old methods and the reform will be inaugurated.

I shall endeavor in this paper to point out some economical methods of pumping water by compressed air, and to suggest how others might be accomplished. Let us consider generally the various methods used to lift water by compressed air, and compare them in such a manner that those interested may better understand the subject, thus enabling them to improve upon these methods when occasion offers. It is discouraging to those who believe that compressed air occupies an economical as well as a useful field to see the various tables, rules and computations offered to the public for calculating the amount of air required to lift water, without a word of explanation that might temper the almost general conclusion that compressed air is a very expensive luxury. It would require a stout heart and a long purse to put in a compressed air pumping plant if the verdict of the various quantity tables were final. One consulting these authorities, would invariably conclude that the efficiencies were so low that only pressing necessity would decide in favor of compressed air.

The percentage of efficiency credited to compressed air in these tables ranges from 15 to 30 per cent. No mention is made of possibilities beyond these numbers, and one is left but the one conclusion—that from four to seven horse power

*Paper read before the Technical Society of San Francisco.

must be furnished to the compressor in order to produce a net yield of one horse power in water pumped, and particularly is this discouraging when enterprising advocates of electricity keep emblazoned before us all that imposing array of efficiencies that seem to almost jostle the revered 100 per cent. from its pedestal. Moreover, all this is misleading besides, for there are efficiencies to be obtained in the proper use of compressed air in pumps that are more than satisfactory, that in fact are difficult to exceed in many instances, and I have tried to make it clear in this paper how to practically realize these results.

from 225 to 130 cubic feet of free air per minute, and the cylinder ratios from 1 to 1 to 5 to 1. It will also be noted that the pressures required for the same cylinder ratios vary 150 per cent. The air pressures given are all receiver pressures, or pressures in the main air pipe, which fact is not mentioned, leaving one to draw the conclusion that, no matter what the pressure in the main is, it is only necessary to install a pump with a large cylinder ratio and use low pressures.

Compressed air in mining is used for driving rock drills, for hoisting and pumping, and the average pressures carried in the mains correspond very nearly to the steam pressures formerly used for the same work, and 90 pounds gauge, independent of altitude, seems to be the standard pressure. This being the case, these tables and pumping data should all be calculated from some such standard basis, with proper co-efficients for variations from the standard pressure, and a table giving the proper cylinder ratios, for different heads, using the standard pressures as a basis, would, it seems to me, be more helpful to those who wish to consult tables for guidance.

In this paper we shall assume 90 pounds to be the standard pressure car-

TABLE No. 1.

For 100 Gallons per Minute. 200 Feet High.

	No. 1.				No. 2.				No. 3.			
Ratio of Air to Water Cylinder.	Quantity of free Air.	Gauge Pressure.	H. P.	Efficiency.	Quantity of free Air.	Gauge Pressure.	H. P.	Efficiency.	Quantity of free Air.	Gauge Pressure.	H. P.	Efficiency.
1-1	134	11.0	29	17								
1.5-1	153	48.8	21	24								
1.75-1	169	36.6	19.5	25								
2-1	181	27.5	16.2	30	130	50	18.2	27	170	50	23.8	21
2.25-1	197	22	15	33								
25-1	206	17.6	13.5	37	137	40	16.4	30	178	40	21.5	23
3-1					145	33	15.2	33	180	33	19	26
3.5-1					152	29	15	33	185	29	18.5	27
4-1					158	25	13.5	37	205	25	17	28
5-1					176	20	12	41.5	225	20	14.7	34

As an example of the information given by some of the catalogues published by builders of compressed air machinery take an example of one hundred gallons of water pumped two hundred feet high. What is the quantity of free air and the pressure required in direct-acting pumps? Reference is made to the table, No. 1, containing extracts from three publications. One hundred gallons per minute, raised 200 feet high, requires, theoretically, 5 horse power. Comparing this with the table, we find that the efficiencies range from 17 to 40 per cent., the pressure from 110 to 20 pounds, the volumes

ried in the mains and that it takes 20 brake horse power to compress 100 cubic feet of free air per minute to that pressure at sea level with a single stage machine. This is more than is called for by the catalogues, but observations from a great many compressors, of many makes, justify me in this statement, and pressures all along the line will follow the same rule.

There appear to be six general forms of compressed air pumps:

First—Displacement pumps for full pressure only.

Second—Displacement pumps using expansion.

Third—Direct acting pumps for full pressure only.

Fourth—Direct acting pumps using expansion.

Fifth—Air lift pumps, single and combined with displacement chambers.

Sixth—Pumps operated by independent motors.

The notations employed will be gauge pressures, unless otherwise specified. Temperatures are expressed in Fahrenheit degrees. The altitude is at zero; that is to say, sea level, and the atmospheric pressure is rated at 15 pounds for the sake of convenience, and one gallon of water, which equals .134 cubic feet, raised one foot high, is the unit of work to be performed.

The first general system of pumps, as before classified, viz., displacement pumps for full pressure only, appear to be the simplest of all, and are those which would naturally be first suggested to the mind. If we have a closed vessel containing water, having a discharge pipe, let us say 210 feet high, connected to its bottom, and if we force air at 90 pounds pressure slowly into this vessel, the air will rise to the top of the vessel and water will be discharged exactly equal in volume to the volume of air forced in, and (90x.068) + 1, or 7, will represent the number of cubic feet of free air required to raise each cubic foot of water. Inasmuch as practice will require a certain additional pressure to give a dynamic head, and as there is a certain amount of pipe friction to overcome, and as some air also is absorbed by the water, the number 7, before stated, can properly be made 9 cubic feet of free air used to 1 cubic foot of water pumped, or, expressed in foot gallons: 1 cubic foot of free air at 90 pounds will perform 1/9x210-.134=175 foot gallons. The 1 cubic foot of free air has received 1/5 horse power, or 6,600 foot pounds of work expended upon it. 175 foot gallons=175x8.3 pounds, the weight of 1 gallon=1,452 foot pounds, or an efficiency of practically 22 per cent., and it will be observed later on that this is better than most ordinary direct acting pumps will do with cold air as ordinarily used.

The efficiency of this system may be in-

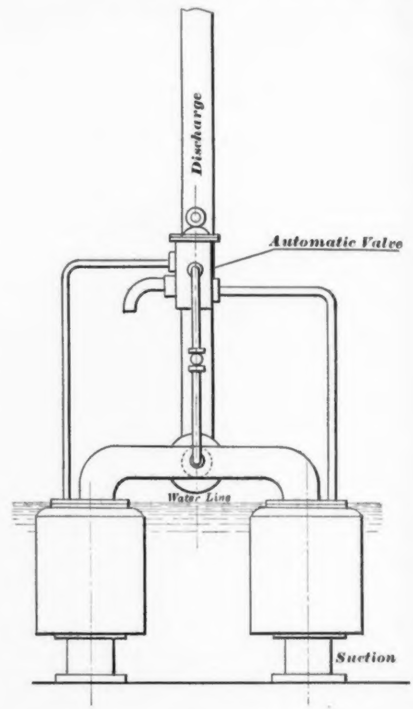


FIG. 1.

creased 15 per cent. by compound compression, or, if the water to be pumped has a higher temperature than the air, as, for instance, in the Comstock, where the water is 120 degrees, the absolute temperature would be 580 degrees, and the efficiency would then be 22x580-520=24.5 per cent. Assuming, for this illustration, that the Comstock is at sea level, the air in this system of pumping may be likened to a flexible plunger having 1 square foot area, making one stroke per minute, and the actual length of stroke

equal to the number of cubic feet of compressed air furnished per minute, diminished by the absorption, leakage, clearance and equivalent quantity necessary to furnish dynamic head and friction and increased or diminished by the ratio of absolute temperature of air and water. It would be proper to range the efficiency from 15 to 22 per cent. The chambers of this pump must be submerged, which limits its usefulness. In a sump, or tank, in a mine, and for lifts within range of ordinary compressors, say up to 250 feet, it will still probably exceed the efficiency pounding of this system, however, will be of the ordinary direct acting pump.

One can readily see that it exhausts its destroy pump valves, its utility gives it a desirable place, but over and beyond this a well-constructed pump of this type has a right to be properly considered in comparison with ordinary direct acting pumps. In the pumps of this type there are generally two chambers, so that while one is filling, the other may discharge, and thus insure a steady delivery, but frequently single vessels are found adequate. cases prove to be the proper installation, The diagram, Fig. 1, gives a general idea of this type of pump.

As may be imagined, the inlet and outlet of the compressed air in the original pumps of this class were controlled by floats, which are unreliable and limit to

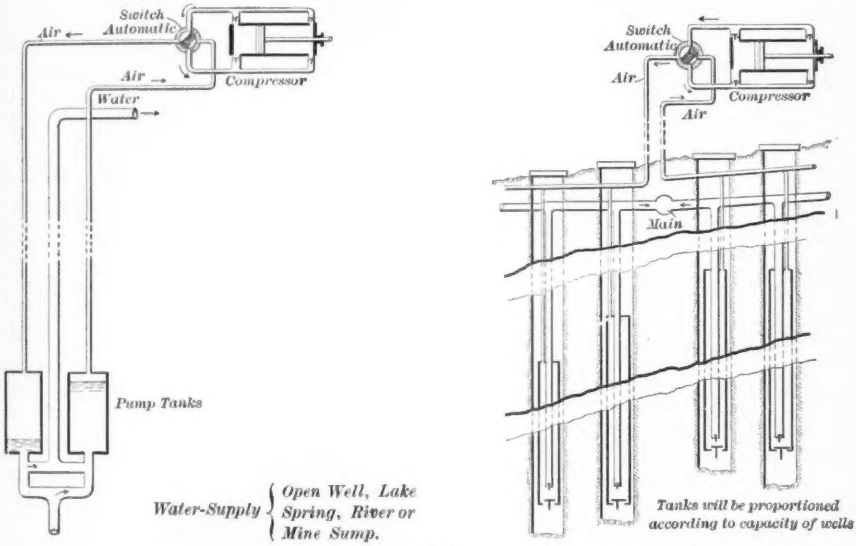


FIG. 2.

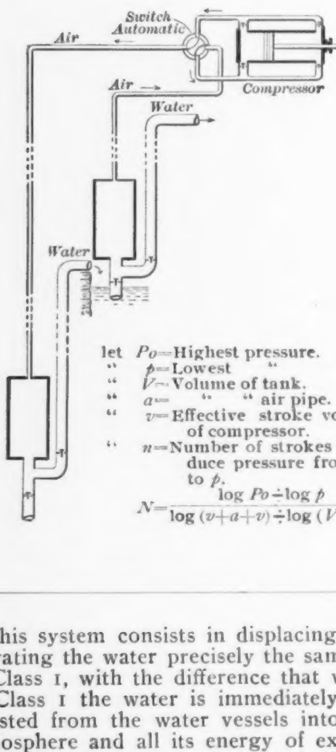
chambers into the atmosphere at full pressure, and all the expansive work contained in the air is lost. A proper comsuggested later on, which will utilize some of this expansion and increase the efficiency materially. Without reflecting, perhaps, engineers have generally discarded this system as too primitive and uneconomical, whereas, in fact, in many instances, it is cheaper by far to install, and often would exceed the efficiency of a direct-acting pump. For handling sewage, or material which would obstruct or a great extent the size and shape of the vessels, and the clearance was excessive. The modern type, however, has eliminated all of these uncertainties, and the pump of the Merrill Pneumatic Pump Co. has a differential controlling valve, situated above the chambers, and this valve is automatic and positive, and the chambers are free from floats. A large number are in use, and being free from many complications which exist in ordinary pumps they may be classed alongside of ordinary direct acting pumps, where sub-

mersion is possible. There is no reason why lifts in two or more stages would not be entirely feasible with this pump.

Class No. 2 consists of displacement pumps using more or less expansion. This class of pumps is best exemplified by the Harris system, owned and operated by the Pneumatic Engineering Co., of New York, and this system is extremely interesting, simple and economical, and, I have no doubt, would in many especially in mines having a steady flow of water at reasonable heads to be handled.

leakage and friction to be about 15 per cent., a statement which deserves credence.

The action of the pump is as follows: There are two chambers placed within suction limit of the sump, or submerged, as desired. An air pipe leads from the compressor to the top of each chamber. There is a single water discharge connected to both chambers, and a single suction. The system is so arranged that while one chamber is filling the other empties, and an automatic switch plays the important part of regulating the en-



let Po = Highest pressure.
" p = Lowest "
" V = Volume of tank.
" a = " " air pipe.
" v = Effective stroke volume of compressor.
" n = Number of strokes to reduce pressure from Po to p.

$$N = \frac{\log Po \div \log p}{\log (v+a+v) \div \log (V+a)}$$

Notes on Operation.

One tank (or group of tanks) is emptied by air pressure while the other is drawn full by suction, the air charge being so adjusted that one tank is drawn full of water just when the other is emptied.

The Switch

Can be automatically operated in either of three ways:

1. By means of the suction in the intake to compressor which depends on the height to which water must be drawn in filling the tanks.
2. By a mechanism that will throw the Switch at a given number of compressor strokes the number required being that which will empty one tank and fill the other.
3. By an electrically controlled mechanism, the circuit being controlled either by floats in the pump tanks or by a pressure gauge on the intake pipe.

Advantages.

1. The expansive energy in the compressed air is fully utilized.
2. There are no moving or delicate parts outside the compressor room except the check valves on water pipes.
3. One compressor can pump water from any number of sources.
4. In mine drainage the tanks may be submerged to any depth.

From Pneumatic Eng. Co., N. Y.

FIG. 3.

This system consists in displacing and elevating the water precisely the same as in Class 1, with the difference that while in Class 1 the water is immediately exhausted from the water vessels into the atmosphere and all its energy of expansion lost, the compressed air in the latter system is allowed to do work in expanding against the compressor piston and thus, theoretically speaking, all its expansive energy is saved, but practically the manufacturers claim the losses in trance and exit of the air. The system is a closed one, and only leakage is replaced automatically.

Suppose one of the chambers filled with water; the air is then admitted at such pressure that the water is expelled and the air pipe and chamber are full of compressed air at the pressure of the water lift, or slightly more. The other tank has in the meantime filled with water. At this point the automatic switch connects the air pipe of the empty chamber with

the intake of the air cylinder and the air pipe of the other chamber with the discharge of the compressor cylinder. It is evident that instantly the air in the first chamber will expand through the compressor and equalize the pressure in the empty air pipe of the second chamber and all clearances. This part of the expansion is lost, but it amounts to but little. The compressor now transfers the air from the first chamber to the second, displacing the water in the second, and the air from the first chamber thus does work upon the air compressor piston in expanding from full pressure to zero. When zero pressure is reached in the first chamber, if it is not submerged, the compressor continues to draw air from it until the water rises and fills it. At this point the first chamber is ready to be discharged, but if there has been leakage the second chamber has not received enough air to complete its discharge, and this is now supplied by a check valve in the intake pipe, which is set to open at a suction pressure slightly above that necessary to draw the water into the chambers. If the chambers are submerged, an ordinary check valve will automatically supply any deficiency in the quantity of air. The second chamber, being completely discharged, the automatic switch reverses and the cycle is complete. Of course everything depends upon the reliability of the switch, which is placed on the air pipes near the compressor, where the engineer can see its operation and adjust it if necessary. It can be automatically operated in three ways: First, by means of the suction which occurs in the intake pipe to the compressor when the water is drawn above its outside level in one of the chambers; second, by a mechanism that will throw the switch at some assigned number of strokes of the compressor, the proper number being that which will empty one chamber and fill the other; third, by an electrically controlled mechanism, the circuit being made and broken by a pressure gauge on the intake of the compressor, or by a float in one of the chambers..

In Figs. 2, 3 and 4 we have diagrams and data supplied me by the Pneumatic Engineering Co., which will be interesting to those who care to investigate this extremely interesting and economical method of pumping by compressed air.

Fig. 5 gives a problem of pumping under 90 pounds pressure which shows in detail the range of the work on the air compressor piston during the progress of changing the air from one water chamber to the other. It will be noted that the net work is even less than the full pressure work at 90 pounds pressure, thus showing that the compression work is practically eliminated, and 90 pounds pressure can be transferred from one receiver to the other at less than one-third of the power required to fill a receiver at 90 pounds pressure, consequently this system should be at least twice as economical as the regular displacement system. The disadvantage is that it requires an independent plant and a double set of air pipes. I have no hesitancy in placing the efficiency at from sixty to seventy per cent., and consider it a very desirable system for mine station pumping.

DIRECT ACTING PUMPS.

The ordinary direct acting pump is the best known of all power pumps, and is the typical example of a motor driven, displacement pump. Its efficiency suffers on account of its large clearance, its apparent inability to realize full stroke and the ill-advised selection of cylinder proportions. In general it is given a mechanical efficiency of 65 per cent. It is not an absolutely complete displacement pump, because the valves are generally arranged to cut off just before the completion of the stroke in order to exhaust the inertia of the moving parts by the time the stroke is finished, and this gives a slight expansion in the cylinder, but this may be neglected in general and the pump put in the displacement class.

If a pump uses full pressure only, it is evident that the more full pressure a compressor diagram shows, the greater will be the efficiency of the system. The lower the air pressure the less the compression work and the greater the proportion of full pressure work, consequently the lower the pressure the more efficient the system. This really refers to the compressor and not to the pump, for the pump works the same whether it receives air at 10 pounds pressure from the compressor or whether it has been expanded from a receiver having a higher pressure, provided the temperatures are constant. If we look for the best efficiency then from direct acting pumps we must put in an independent compressed air system and carry a low pressure. We can hardly

THE COMPOUND DIRECT-AIR-PRESSURE PUMP WITH ADJUSTING RECEIVER.

Computations for Proportioning the Parts and a Graphical Presentation of one Cycle of Operation.

SYMBOLS AND NUMERICAL VALUES.

P' = Absolute Max. pressure in lower tank.
P'' = " " " " upper "
P' & P'' = " Min. " " either "
a' = Vol. of air pipe to lower "
a'' = " " " " " upper "
V' = " " lower "
V'' = " " upper "
R = " " Receiver.
v = " " compressor stroke.
n = Number of compressor strokes.
Pn = Variable pressure in tanks.
W = " work per stroke.
Vn = " water volume delivered per stroke.

FORMULAS.

$$V'' = \frac{P'(v'+a')+p''a''-p'a'}{P''} - a'' \quad . \quad . \quad I.$$

$$R = \frac{P''(v''+a'')-P'(v'+a')+p'a'-p''a''}{P'-P''} \quad II.$$

$$Pn = Po \left(\frac{v+a}{v+a+v}\right)^n \quad . \quad . \quad . \quad . \quad III.$$

Po = initial pressure, Pn that after in strokes.

$$N = \frac{log.\ Po - log.\ Pn}{log.\ (v+a+v) - log.\ (v+a)} \quad . \quad . \quad IV.$$

$$Wn = Px\ v\ \ log.\ \frac{Po}{Px} \quad . \quad . \quad . \quad . \quad . \quad . \quad V.$$

$$Vn = \frac{Pn}{P'}v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad VI.$$

The proper value for v is found by trial in Eq. IV.

THE PROBLEM.

Proportion a System to lift 66 cu. ft. (500 gals.) per minute 200 feet in the lower stage and 650 gals. (87 cu. ft.) per minute, 175′ in the upper stage. Assuming lengths of air pipes to be 500′ to lower and 300′ to upper tanks.

Note:—In the following computations it is assumed that no change in temperature occurs and friction of air and of water in pipes is neglected.

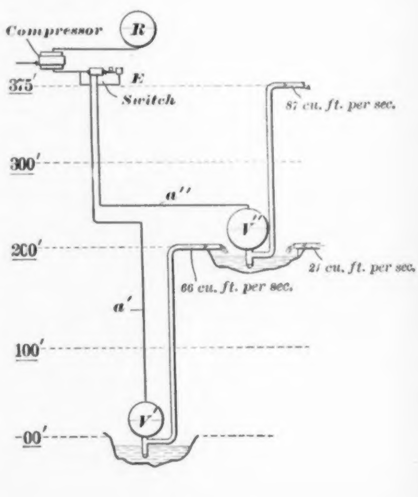
SOLUTION.

Horse Power:—From figures given above the average net Horse Power = 55. But the max. rate of work per stroke is 10900 ft. lbs. (see ordinate at K.) Assuming the compressor to work at 90 revolutions (or 3 strokes per sec.) this will give about 60 H. P.

Air Pipes:—If the volume of compressor stroke is previously known the max. velocity in air pipe of known area can be found by observing that immediately after switching the whole volume of compressor stroke goes through the air pipes.

Otherwise an approximate rate is: The max. air volume = 6 times the average water volume discharge. In this case the rule gives 5.5 cu. ft. per sec. of air at 102#. Hence select air pipes 4″ diam.

Tanks:—They should not be less than 10 times the vol. of air pipe. Hence assume V′=450 cu. ft. Then if no receiver were attached V″ would be computed by Eq. I. which would give V″ =525; but by conditions of the problem, V″ must be = 1.3 V′=585. This requirement can be



satisfied by attaching a receiver whose volume will be computed by Eq. II. Whence R=497. In practice make V″ and R larger to permit adjusting, which can be done by pumping water in or out of R.

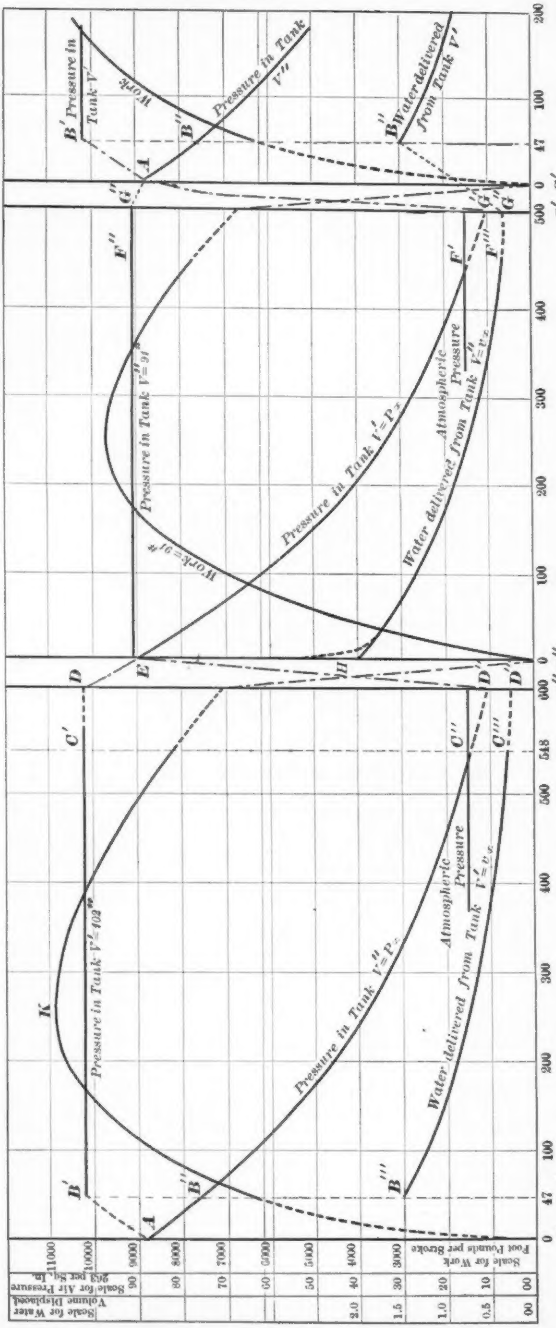
Notes on the Operation: When air is switched out of V″ it expands into pipe a' and thereby drops from 91♯ to 88♯ (G″ to A) then compressor forces air into V′ but no water will be delivered until pressure in V′ reaches 102 In the meantime pressure in V″ will be worked down to 76.5 which will require 47 strokes (see A to B′ and A to B″).

When air is switched out at V′ we will have V′ + R + a' at 102♯ while only 91♯ is necessary to force water out of V″. Hence water will discharge without further action of compressor until all pressures drop to 91♯.

The volume of water thus displaced will be 96 cu. ft. This cannot be properly shown on the diagram. It occurs between D‴ and E‴ but as these points are coincident in time the effect will be to run the delivery curve up as shown in the clotted line near E‴.

Formulas III and IV do not apply after Pn falls below atmospheric pressure. for V′ (or V″) is then a variable. Hence the broken lines between C and D and F and G are not computed.

The two lines in each pair of heavy verticals S″ S″ and S′ S′ are coincident in time. The intervening space is for convenience in showing connections between curves.



Number of Compressor Strokes.

FIG. 4.

HARRIS' COMPOUND PRESSURE PUMP.

A. E. Chodzko.

Number of Double Strokes.	Pn Absolute Pressure per Sq. In. after Expansion.	$\frac{Po}{Pn}$	$\frac{Pn}{Po}$	$\left(\frac{Pn}{Po}\right)^{\frac{1}{r}}$	Effective Adiabatic Work of Compression and Delivery. Foot-Lbs.	Effective Isothermal Work of Expansion. Foot-Lbs.	Net Work of Compression and Delivery. Foot-Lbs.
1	88.9	1.18	0.847	.89	25,704	19,580	6,124
2	73.5	1.39	0.719	.79	24,768	15,991	8,777
3	64.1	1.63	0.614	.71	23,509	12,937	10,572
4	54.4	1.92	0.521	.628	22,824	10,339	12,485
5	46.2	2.27	0.44	.557	21,270	8,142	13,128
6	39.2	2.66	0.376	.497	19,960	6,267	13,693
7	33.3	3.14	0.318	.441	18,360	4,687	13,673
8	28.3	3.7	0.27	.39	16,517	3,347	13,170
9	24	4.36	0.23	.349	15,480	2,195	13,083
10	20.4	5.13	0.195	.31	13,738	1,231	12,507
11	17.3	6.05	0.166	.28	12,845	401	12,444
12	14.68	7.13	0.14	.246	11,088	-296	11,384
							141,040

Work of simple compression of 80 cu. ft. of free air to 90 lbs. gauge at 6600, 528,000
Work of compound compression " " " " 446,306

Efficiency of the system referred to compound is therefore, $\frac{446,306}{141,040} = 3.09$

and referred to simple is . . . . . . $\frac{528,000}{141,040} = 3.75$

Po initial absolute pressure in tank.
final " " in compressor = 90 lbs. *g.* = 1047 lbs. absolute.
Pn absolute pressure after the *n*th double stroke.
Pa " atmospheric pressure.

$$Pn = Po\left(\frac{V+a}{V+a+v}\right)^n$$

V volume of tank = 8 cu. ft.
a " pipe = 3.24 cu. ft.
v " compressor cylinder = 2 cu. ft.

$Pn = 104.7 \times 0.849^n$ / log. $Pn = 2.019947 + n \times \bar{1}.928965$
Effective isothermal work of expansion.
$We = 267.87\ Pn - 4233.6$
Effective adiabatic work of compression.

$$We = \frac{v}{r-1}\left[r\left\{P_1\left(\frac{Pn}{P_1}\right)^{\frac{1}{r}} - Pa\right\} - \left(Pn - Pa\right)\right]$$

Theoretical actual work done in lifting water = 8 × 62.5 × 2.10 = 105,000 foot-lbs. allowing 85% mechanical efficiency. Real work done = 89,250 foot-lbs.

$$\frac{89,250}{141,000} = 63.3\%$$

FIG. 5.

imagine that this would be generally done, and consequently we must count on the standard pressure of about 90 pounds for our economies and proportions.

After comparing the various tables of compressed air quantities for direct acting pumps, it appears that the calculations of William Cox are most reliable, and they agree very nearly with practical results that I have noted. He, however, like the others, considers that the pressure used by the pump is receiver pressure. His principal formulae are as follows, based on 100 feet per minute of piston speed. Other speeds will naturally be in proportion.

Diameter water cylinder=.54 gallons raised.

(Diameter air cylinder)2=.5xheadx(Diameter of water cylinder) 2 × gage pressure.

Volume of free air=.63x(Diameter of air cylinder) 2x (1+.068 gage pressure) and, in general, without regard to any factors but quantity, head and pressure, we have the volume of free air=.093 foot gallons gage pressure x (1+.068 gage pressure).

In using these it must always be borne in mind that the pressures given are receiver pressures; that is to say, that the compressor furnishes air to the mains at pressures called for in the tables, and if any higher pressures are carried in the mains, such as 90 pounds, and if then the air cylinder of the pump is so large that the air is wiredrawn to it, then the quantities of compressed air given should be multiplied by a constant, such as given in Column 6, Fig. 6, when the pipes are short between the main and the pump, as occurs generally in a shaft.

The constants in Column 6 are simply about 70 per cent. of the ratio of the absolute temperatures due to the expansion of the air from 90 pounds to the pressures indicated in the tables, and the horse power will not be the power required to raise the pressure from atmosphere to the working pressure, but always that required to deliver it into the mains. This fact makes sorry work for efficiencies.

Inasmuch as most pumps are in the shaft near the main, a very short pipe connects them to the main, and the air is expanded through this short pipe to the pump, for pressures less than that in the main. This expansion reduces the temperature of the air entering the pump, to quite a marked degree. Not by the theoretical amount due to the pressure drop, for some heat from external sources can be supplied, and wiredrawing furnishes a disputed amount also. While I have made no experiments on this subject, I have assumed that less heat would be given to this expanding air than a good water jacket would take out of the air during compression, and I have assumed the temperature to drop 70 per cent. of that, due to the pressure drop. This reduces the air volume and adds to the quantity consumed by the pump and consequently lowers its efficiency.

It would be good practice to let this cold air gain normal temperature before reaching the pump cylinder, which can be done by passing the water being pumped into an enlargement in the discharge pipe within which is a coil through which the air is passed, but if no such device is used and the air pressure in the mains is 90 pounds we shall find that the table, Fig. 6, expresses about the real condition of affairs for a pumping effort of 10,000 foot gallons.

In explanation of the table:

10,000 foot gallons=83,000 foot pounds=2.5 horse power, theoretical.

Column 1—Gauge pressures in air cylinder of pump.

Column 2—Volume of free air required, calculated from Cox's computer, No. 76.

Column 3—Horse power corresponding to above volume, calculated from same computer.

Column 4—Ratio of the gauge pressures in Column 1 to 90 pounds, standard mining pressure.

Column 5—Adiabatic temperature ratios corresponding to the pressure ratios in Column 4.

Column 6—Gives the practical temperatures, ratios being 70 per cent of 5.

Column 7—Is Column 2 multiplied by Column 6.

Column 8—Horse power calculated for Column 7 by Cox's computer, No. 76.

Column 9—Percentages of Column 3.

Column 10—Percentages of Column 8.

Conclusions from table:

First—The lower the air pressure in the main, with cylinders designed properly, the greater the efficiency, reaching as high as 30 per cent.

Second—The efficiency drops immediately if the air is expanded through the throttle into an air cylinder which requires less pressure than the main.

Third—At standard mining pressure of 90 pounds the efficiency is about 17 per cent. with properly designed cylinders, and probably drops as low as 12½ per cent in pumps where "just one turn of the valve is open."

Fourth—Very little loss occurs in using pressures within 10 per cent. of the pressure in the main, which is ample to impart proper dynamic head to the pump.

If compound compression should be used, then the efficiencies mentioned can be increased 15 per cent., and they will range then as high as 34.5 per cent. for low pressures, and from 19.55 to 14.5 for standard mining pressures.

If the air is reheated, so that the pump cylinder receives it at 300 degrees Fahrenheit, and if no account is made of the cost of reheating, then the efficiencies for low pressure and simple compression will be 42 per cent., and compound compression 48 per cent., and for standard mining pressures, for smple compression, 24 to 17.5 per cent., and for compound compression, 27½ to 20 per cent.

According to the above table, at standard mining pressure the efficiency, using cold air, is 17 per cent. at maximum. According to our statement, if 20 horse power produce 100 cubic feet of free air per minute compressed to 90 pounds, 1

1	2	3	4	5	6	7	8	9	10
Press. of Air.	Volume. Cox.	H. P. Cox.	Ratio Comp. Referred to 90 Lbs.	Adiabatic Increase Ratio.	Practical Increase Ratio.	Increased Volume.	H. P. at 90 Lbs.	Eff. Cox.	Eff.
20	113	8.4	3	1–37	1–26	142	28.5	30	9
25	103	9	2.6	1–32	1–22	125	25	27	10
30	97	9.6	2.3	1–27	1–19	115	23	26	11
35	93	10.1	2.1	1–24	1–17	108	21.5	25	11.5
40	89	10.6	1.9	1–2	1–14	101	20	24	12.5
45	87	11.2	1.7	1–16	1–12	97	19.7	22	12.6
50	85	12.0	1.6	1–14	1–11	94	19.1	20.5	13
55	82	12.5	1.5	1–12	1–09	89	18	20	14
60	80	12.6	1.4	1–10	1–07	85	17	19.8	14.7
65	79	13	1.31	1–07	1–06	84	16.8	19.3	15
70	78	13.4	1.24	1–06	1–05	82	16.4	19	15.3
75	77	13.6	1.17	1–05	1–04	80	16	18.5	15.6
80	76	14	1.1	1–04	1–03	78	15.6	18	16
85	75	14.5	1.05	1–02	1–02	76	15.2	17.5	16.5
90	74	14.8	1	1–0	1–0	74	14.8	17	17

10,000 foot-gals. = 83,000 foot-lbs. = 2.5 H. P. theoretical.

EXPLANATION OF TABLE.

Col. 1—Gauge pressures in air cyl. of pump.
Col 2—Is the volume of free air required, calculated from Cox's computer.
Col. 3—Horse power corresponding to above volume, calculated from same computer.
Col. 4—Ratio of Gauge pressures in Col. 1 to 90 lbs. Standard Mining Pressure.
Col. 5—Adiabatic temperature. Ratios corresponding to pressure ratios in No. 4.
Col. 6—Are practical temperature ratios, being 70% of No. 5.
Col. 7—Is Col. 2 multiplied by Col. 6.
Col. 8—Is H. P. calculated for No. 7 by Cox's computer 76.
Col. 9—Are percentages of Col. 3.
Col. 10—Are percentages of Col. 8.

FIG. 6.

cubic foot will cost 6,600 foot pounds of work. Seventeen per cent of this would be 1,122 foot pounds of useful work that the one cubic foot of free air would perform; 1,122 foot pounds is 135 foot gallons.

I have measured the exhaust of many pumps using air at from 80 to 90 pounds, and I have found their work to be approximately 135 foot gallons for each cubic foot of air, and I have used this figure in all my calculations for ordinary pumps, properly proportioned. Thus, to lift 200 gallons a minute 200 feet high, would be 40,000 foot gallons. This, divided by 135, would require 300 cubic feet of free air compressed to 90 pounds, which in turn requires 3x20, or 60 horse power to produce it. If compound compression be used, I increase the 135 foot gallons by 15 per cent. and call it 155 foot gallons, and if reheating is used, in either case, I

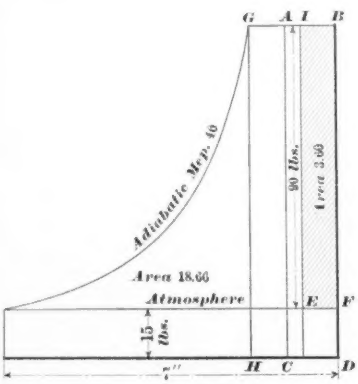


Diagram of Ordinary Direct-Acting Pump.

FIG. 7.

increase the 135 by the ratio of absolute temperature which I am satisfied the pump receives.

The efficiency of the direct acting pump is seen from diagram, Fig. 7, as follows: With a simple compressor the M. E. P. of compression is a little more than the M. E. P. adiabatic, say, 40 pounds. This corresponds to an area on this card of M. E. P.=Area x Spring Length of Card 40=Ax15-7, or 280-15=18.66 square inches. The adiabatic volume of G, B, D, H shrinks to A, B, D, C before arriving at the pump. The pump having a mechanical efficiency of 65 per cent., the volume I B, F, E is all that really does useful work. That area is .60x6=3.60 square inches, and 3.60-18.66=19 per cent., which compares nearly with our other figures.

We found simple displacement pumps, Class I, giving 175 foot gallons of work, and direct acting pumps, Class II, giving 135 foot gallons of work. This might be anticipated, because in Class I the air is used isothermally throughout, the pressure is always exactly what is necessary and clearance is small and no mechanical movements to overcome.

Referring again to the table, Fig. 6, and remembering that we have assumed 90 pounds as our standard pressure in the mains, we note how serious a loss we would entertain if we used a pump having such a large air cylinder that the working pressure was only 20 pounds. One not skilled might expect to get 30 per cent. efficiency, but he would really get about 10 per cent., or just 300 per cent. out of the way, and this justifies the remark that I have heretofore made that these catalogue tables are misleading. Except for extremely small quantities and for sinking pumps I cannot justify the use of simple, direct acting pumps for compressed air service.

Simple displacement pumps, mentioned in Class I, can be made to use the air with at least partial expansion, and I suggest the following for consideration and experiment. It is new to me, and occurred to me while searching for a cheap and economical means to do some air pumping. We will take the same problem of work at 90 pounds pressure, and, in order to make the problem simple, I have made it purely theoretical, and we can supply whatever efficiency coefficient we deem appropriate.

(To be Continued.)

The Use of Water Powers by Direct Air Compression.

Probably one of the oldest applications of the use of water power to the wants of man was a form of hydraulic air compressor which operated as an entrainment apparatus, and is the well-known water bellows or trompe of the Catalan forges.

This apparatus, briefly described, consisted of a bamboo pole disposed at a slight inclination from the perpendicular, into the upper end of which a stream of water was led, entraining air with it in its downward passage. The lower end of this bamboo pole was introduced into a bag made of the skin of some animal,

THE MAGOG DAM AT HIGH WATER.

the air being allowed to escape from the water into the upper part of the bag, from whence it was led by pipes or tuyeres to the forge, the water being allowed to escape from the lower edge of the bag. From this original device a great many improvements have been worked out, and besides this a number of other forms of hydraulic air compressors, or of compressors using other liquids for compressing air or other gases, have been designed.

The movement toward fuller utilization of the yet unrealized water resources of the world is one which is constantly quickening. With greater use comes larger study of adaptation of machinery and methods of water-power development and transmission. The peculiar means described by Mr. Webber has more than a passing interest. --Editors' Engineering Magazine.

A very simple form is a displacement apparatus,* consisting of a water reservoir and two air chambers of about three times the capacity of the water chamber. Water is led into the reservoir, compressing the air contained in it into the two chambers and giving a pressure of about 1.6 atmospheres.

Siemens invented an apparatus on the principle of the steam injector, but the use of this was confined principally to the production of a vacuum; it is used to operate the pneumatic dispatch tubes in London. It has also been used for blast purposes in Siemens' furnaces and in sugar works.

Another quite ingenious device, shown in a patent granted to W. L. Howe, consists of two flat plates enclosing an air space from which a pipe leads to the atmosphere. The upper plate is perforated with conical holes, the smaller end being adjacent to the air-space between the two plates. Directly opposite the apertures of the upper plate are corresponding conical apertures in the lower plate, with the smaller end of the aperture next the air space, the lower and larger part of the conical openings being prolonged by tubes; the upper plate is kept under a head of water; the water jet, passing across the thin air-space referred to, draws in the air through the large air pipe and compresses it through the smaller orifices.

Another device using a somewhat similar principle was invented by M. Romilly† and consists of a conical tube attached to an air reservoir by its larger end, and having a check valve interposed in the passage so as to prevent the air from escaping. Water is then injected into the smaller end of this conical tube through an ajutage in the form of a liquid vein at a given pressure, which entrains the air with it and causes it to be compressed in the reservoir. But the apparatus just described did not really employ the same methods as those used in the old trompe. One of the first inventions carrying out this idea was made by Mr. Frizell, of Boston, Mass. His invention made use of an inverted syphon having quite a little horizontal run be-

*Appleton's Cyclopedia of Applied Mechanics, fig. 138, page 37.

†Appleton's Cyclopedia of Applied Mechanics, fig. 139, page 37.

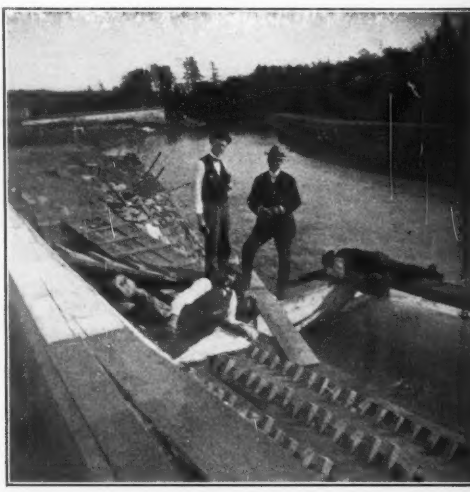
tween the two legs. A stream of water was led into the upper end of the longer leg, and at the top of the horizontal run between the two legs of the syphon was provided an enlarged chamber in which the air would separate from the water, the water being then led off from the lower part of this air chamber and passed off through the shorter leg of the syphon, the pressure of the air accumulated in the air chamber being therefore due to the height of water maintained in the shorter leg of the syphon. This application of carrying upward the water, after the air was separated from it, so as to produce a considerable pressure upon the air, seems to have been oriignal with Mr. Frizell, and in this feature his device differs from the old trompe.

Mr. Frizell made two working models of this type of apparatus. In the first one the legs of the syphon were 3 inches in diameter, the head of water being 25 inches, and an efficiency of 26½ per cent. was obtained. A larger apparatus was then constructed at the Falls of St. Anthony, on the Mississippi River, a few miles above St. Paul; the longer leg of the syphon in this plant was 15 inches by 30 inches and the short leg of the syphon 24 inches by 48 inches in section; the height of water above the air chamber was 29 feet. The head in feet varied from .98 to 5.2, the first head being just sufficient to cause a flow through the pipes. The working head varied from 2.54 feet to 5.02 feet and the efficiency from 40.4 per cent. to 50.7 per cent., the quantity of water in these cases varying from 5.92 to 11.89 cubic feet per second.

Mr. Frizell estimates from the experiments he has made that with a shaft 10 feet in diameter, a depth of 120 feet, and a fall of 15 feet, the efficiency would be 76 per cent., and with a head of 30 feet and a fall of 230 feet the efficiency would be 81 per cent.

Another device, differing somewhat from that of Mr. Frizell, was invented by A. Balochi and A. Krahnass in 1885, and consisted of a syphon carrying water from an upper reservoir down to another reservoir situated at a lower level, the lower end of the syphon being projected through an inverted vessel placed nearly at the bottom of the second reservoir. Just beyond the bend of the syphon, and in line with the vertical axis of the longer leg thereof, was an air pipe projecting into the descending column of water, thus entraining the air with the descending column, and carrying it down into the inverted chamber, where the air escaped from the top and the water passed out from the bottom of the inverted vessel into the lower chamber. This also produced pressure on the air in the top of the inverted chamber, due to the height of the water column upon it.

Another device, patented by Arthur in 1888, differs from the last in having a stream of water led directly into the top of the vertical pipe. Inserted into the mouth of this pipe was a double cylin-



THE WEIR BOX AT MAGOG, FROM THE BRIDGE.
Observers taking readings from the hook gauges.

drical cone, making an annular air passage surrounding the mouth into which the water was delivered. The water, after passing through the upper cone and there being compressed and its velocity increased, then passed into the inverted cone, where the velocity was somewhat decreased and the water became more diffused. This lower cone was perforated with holes opening into the annular air chamber previously described, causing air to be entrained with the falling water. Inside of this down-flow pipe was a ver-

tical delivery pipe for the compressed air, having its lower end enlarged and open at the bottom. Projecting upward into this enlarged air-delivery pipe was a water

THE WEIR, SHOWING FORM OF WAVE CREST.

escape pipe through which the water passed after having parted with the air. This escape pipe was in the form of an inverted syphon and maintained a pressure on the air in the delivery pipe, due to the elevation of the water at its discharge point above the air line in the large end of the delivery pipe.

A number of other patents on apparatus of this type were issued to Charles H. Taylor, Nos. 543,410; 543,411; 543,412, July 23, 1895; his invention consisted principally of a down-flow passage having an enlarged chamber at the bottom and an enlarged tank at the top. A series of small air pipes were projected into the mouth of the water inlet from the large chamber at the upper end of the vertically descending passage, so as to cause a number of small jets of air to be entrained by the water, Taylor seemingly having been the first one to introduce the plan of dividing the air inlets into a multiplicity of smaller apertures evenly distributed over the area of the water inlet.

Taylor at first seems to have attempted to utilize centrifugal action in causing the separation of the air and water in the large chamber at the bottom of the compressed column, but afterward abandoned this scheme and used, instead, forms of deflected plates in combination with a gradually enlarging section of the lower end of the down-flow column in order to decrease the velocity of the air and water and cause partial separation to take place, and also using the deflector plates to cause the water to change its direction of flow, evidently with the idea that the air would escape more readily.

The latter improvements on this device have been in the method of introducing the air into the mouth of the downwardly flowing water column, so as to insure the largest proportion of air being taken down with the water, and in methods of decreasing the velocity of the combined air and water at the bottom of the descending column, causing the water to part more readily with the air, the water then passing out at the bottom of the enlarged chamber into an ascending shaft, maintaining upon the air a pressure due to the height of water in the uptake, the air being led off from the top of the enlarged chamber by means of a pipe.

COMPRESSOR HEAD TANK AND WEIR.
The air compressor is blowing off.

The first one of these compressors on the Taylor principle was installed at Magog, Quebec, to furnish power for the

print works of the Dominion Cotton Mills Company. The head of water is 22 feet; the down-flow pipe is 44 inches in diameter, and extends downward through a vertical shaft 10 feet in section and 128 feet deep. At the bottom of the shaft the compressor pipe enters a large tank 17 feet in diameter and 10 feet high, which is known as the air chamber and separator.

THE MAGOG MILL AND WEIR.

All the water passing over the weir has passed down through the air compressor.

A series of very careful tests on this plant demonstrated that out of a gross water horse power of 158.1, 111.7 horse power of effective work in compressing air has been accomplished, giving, therefore, an efficiency of 71 per cent. It is found that the air after compresion shows a very considerable decrease in moisture from that of the air entering the compressor, although in contact with the water all the time. This is probably due to the moisture in the bubble of air being pressed or squeezed out to its surface and then absorbed by the surrounding water. The air is compressed at the temperature of the surrounding water and the compression is isothermal. Owing to these facts there is no loss by heat of compression and again by radiation, in using the air, and there is a practical result which is of more importance: the hydraulically-compressed air can be expanded down to a temperature much below the freezing point, while atmospheric air with its usual amount of moisture, mechanically compressed, cannot be used at all, owing to the freezing up of the exhaust passages of the motor in which the attempt to use it is being made.

The accompanying photographs give an idea of the extent of the plant and of the volume of water used. The last one, showing the air carried in suspension, is especially interesting. The air cloud may be traced in the water quite as distinctly as it is shown in the photograph, for 40 or 50 feet below the weir.

William O. Webber,
in " The Engineering Magazine."

VIEW TAKEN BY POINTING THE CAMERA DIRECTLY DOWNWARD OVER THE EDGE OF THE WEIR.

The clouds are made by the finely-divided particles of air carried in suspension. In the limpid Magog water these may be traced 40 or 50 feet below the weir.

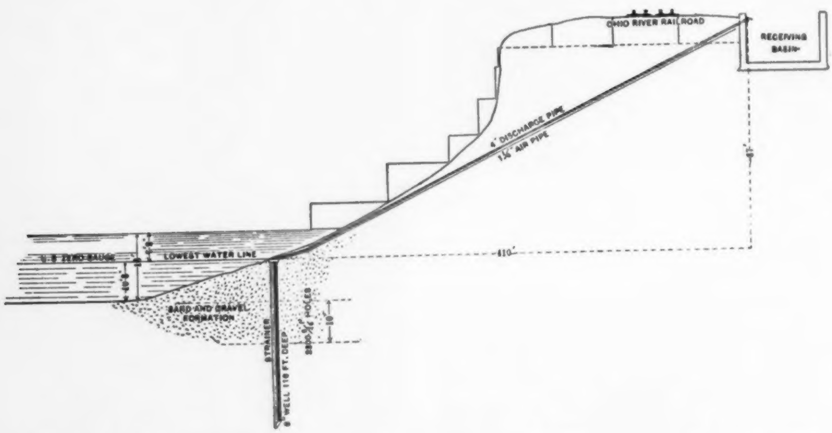
Lifting Water by Compressed Air.

It is only within recent years that moderately deep well pumping by means of compressed air has become at all common. Under favorable conditions the system possesses several decided advantages over all other methods. Among these may be mentioned the absence of all moving parts, in the way of valves, pistons, rods and packings necessarily located a hundred feet, or several times that distance, down in a well where they are difficult of access at all times, and which sooner or later become worn or broken, when they must be taken out to be repaired. All these parts are done away with in the air lift system. Nor does sand or grit affect the working of this system in any manner. There is not a valve or attachment of any sort whatever placed in the well, simply two ordinary pipes. The necessary machinery is located in the engine room, where it is readily accessible at all times.

The object of this article is chiefly to illustrate two quite novel features in the adaptation of the system to pumping water from muddy streams flowing in deep channels. To make this entirely clear, a brief description of the air lift system will not be out of place.

First, there must be an air compressor—that is, an engine that condenses or compresses air to the necessary pressure —discharging into a metal tank called the air receiver. To this a pressure gauge and safety or escape valve are attached, which are identical in all respects to those commonly found on steam boilers. From the receiver a small gas pipe is led to the well and thence downward to near the bottom, where it enters the water discharge pipe; or a series of air conducting pipes may be attached to the receiver and connected to a series of wells situated closely together or remotely at varying distances.

Suspended in each well is a water discharge or conducting pipe, also reaching nearly to the bottom or as far down as may be desired. This pipe may be of any desired size, but is usually several times that of the air pipe in the proportion of 4 diameters to 1, or 4 to $1\frac{1}{4}$, depending on circumstances.



LIFTING WATER BY COMPRESSED AIR.—FIG. 1.—PROFILE OF POINT PLEASANT WATER WORKS.

The air pipe is usually arranged to follow closely along and outside the discharge pipe to its lowest extremity, where it is fitted with a return bend and nipple, as shown in illustration, Fig. 2. It will be observed that the air from the receiver is thereby discharged upward directly into the bottom of the water discharge pipe. It has been the practice of some engineers to attach a brass nozzle at the extremity of the air pipe. Various styles of these are offered, some being

patented, for which the makers claim decided advantage; but it has been ascertained that in this case nothing is better than something (anything). A free discharge of air directly into the foot of the suspended discharge pipe is all that is necessary.

The effect of discharging highly compressed air into the bottom of the discharge pipe is to displace some of the water in it, lessening the gravity of what remains until overcome by the greater pressure of the solid column of water outside of the discharge pipe within the well. Both the air and water in the suspended pipe are forced upward by this resisting pressure and discharged at the top of the well or outlet of the suspended pipe. It will therefore be apparent that as long as there is sufficient depth and flow of water into the well to constantly refill the discharge pipe, and air is supplied to reduce the gravity of that in the discharge pipe, the operation, as described, will continue.

There is, however, one important condition to the successful operation of the air lift system. There must always be ample depth of water in the well to insure sufficient resistance at the foot of the discharge pipe to force the lightened column inside the discharge to the top of the well. This is termed "submergence." Well informed engineers who have made a study of the system say the submergence should be 50 to 60 per cent. By this is meant 50 or 60 feet of water to each 100 feet depth of total lift. That is, if the well is, say, 200 feet deep, and it is desired to discharge the water into a tank situated 50 feet above the top of the well, there must be not less than 125 feet (50 per cent. of 250) to 150 feet (60 per cent.) of water in the well at all times. A less depth would probably render the system useless, as the resisting pressure would be insufficient.

It is customary to discharge the water directly into a tank or receiving basin situated immediately above or closely alongside of the well, with very short, if any, lateral conveying pipes.

During the past 12 months there has been constructed at Point Pleasant, W. Va., on the bank of the Ohio River, a water works employing the air lift system to obtain water from the river, in which this practice was radically changed.

All the machinery was located above the highest known flood line, which is over 60 feet above the lowest river stage (U. S. zero gauge). The franchise

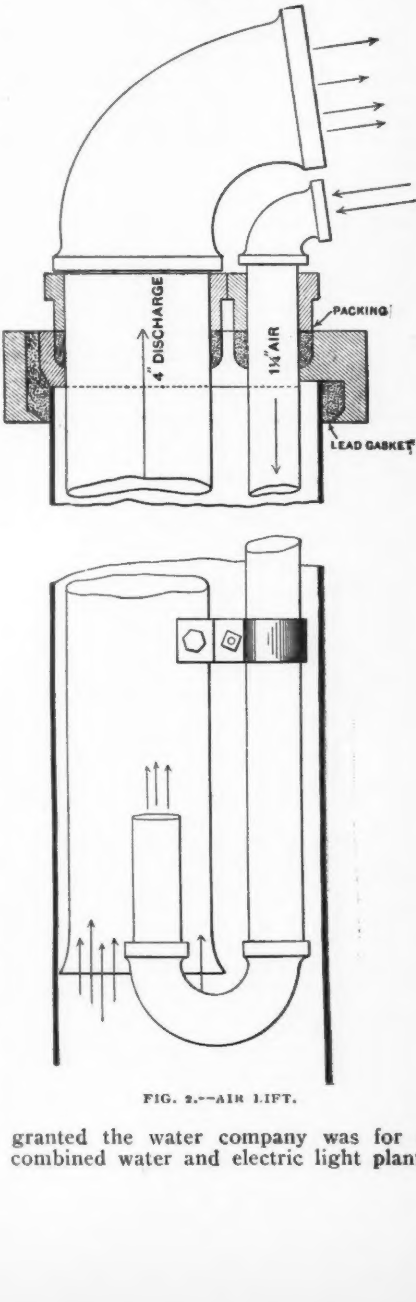


FIG. 2.—AIR LIFT.

granted the water company was for a combined water and electric light plant,

and specified that water was to be taken from the Ohio River. The most desirable site obtainable for the works was about a mile above the town, but the Ohio River Railroad tracks at this point were too close to the river bank to permit the erection of the works on the river side of the railroad. The power and pumping house had therefore to be located about 200 feet distant from the top of the bank, about 400 feet laterally from low water point in the river and 67 feet above it, as shown in Fig 1.

To have constructed a pumping well of sufficient depth and size to accommodate pumps to draw water from the river channel at zero stage and a tunnel to the river would have made the cost of the works so great that sufficient capital could not have been secured to erect them. Some other and less expensive system had to be adopted. Manufacturers of water works machinery were consulted and various plans and systems considered. Finally it was determined to adopt the air lift system, and a hydraulic engineer was employed to make specifications and plans. He proved so unreliable or ignorant of what was required that his services were dispensed with.

The Howell & Shanklin Construction Company, of Charleston, W. Va., were then invited to submit plans and specifications. These were promptly adopted, and a contract was made with them to erect the works entire, which were completed to the last detail just as planned and specified by them.

The use of the air lift system would require wells deep enough to obtain a submergence sufficient to overcome the 67 feet bank lift, plus the depth of the wells and friction of about 500 feet of discharge pipe from the wells to the receiving basin placed obliquely up the river bank. Just here the algebraical x in the problem was found.

At a meeting of the Central States Water Works Association, held in Cincinnati, September, 1899, the writer sought information regarding the application of the air lift system to such situations.

When it was stated that it was the intention to take water from wells sunk in the channel of the Ohio River and discharge it into a basin situated as described, the discovery was made that the problem was not only new but of very doubtful solution. There was no reliable information obtainable from that source on this particular feature of the enterprise.

Later, an engineer, representing one of the oldest builders of air compressors and who has had many years' experience in this line, after a personal examination reported the situation to his firm, who declined to furnish machinery with any guarantee of success because of the probability that when the air reached the sloping pipe up the bank it would pass the water and escape, the water returning to the wells.

Nothing daunted, the contractors proceeded with the works. Presuming that the wells would always be full if located and sunk at low water line, it was decided to make them 110 feet deep. The calculation was based on 60 per cent. submergence as being ample to overcome both lift and friction.

Fig. 1 is an exact copy of a profile of the river bank made by the city engineer of Point Pleasant, and clearly shows the difficulty encountered. Careful soundings of the river channel were made, and it was found that there were several feet depth of sand and gravel forming the river bottom at this point. Well casing 10 inches inside diameter was driven to the rock, about 40 feet in depth. This casing was perforated with hundreds of ¼-inch holes, commencing at about 10 feet from the top, and extending about 10 feet downward. After the 10-inch casings were in place 10-inch holes were drilled in the underlying rock 116 feet deep and cased 8 inches inside diameter from bottom to top. This casing was also perforated similarly to the outer one, only the holes were larger—5-16 inch. The space between the two casings was tightly calked at the top to prevent water entering the wells at this point. Four-inch discharge pipes and 1¼-inch air pipes were properly fitted and suspended in each of the wells, with their extremities 110 feet below the top of the 8-inch casing.

Both pipes were suspended from a water tight cap, Fig. 3, resting on the top of the 8-inch casing shown in Fig. 2. It will be observed that no water can enter these wells except through the perforations in the casings, which are 10 feet to 20 feet below the flowing water in the river. None can enter at the bottom.

It was the desire to allow the river water to enter the wells only through the perforations after having passed through the strand strata mentioned, which would serve as a filter. Before proceeding further, I wish to state that this feature has proved successful beyond expectation. However muddy the river may be, the water taken from the wells is bright and sparkling at all times.

Just when the wells were completed and the pipes in place, and extended up the sloping river bank a short distance, the river rose over the wells. The pump and air compressor builders were weeks behind promised delivery, and for two months the wells stood unused as described. In the meantime the reservoir, receiving basin and power house were completed and the work advanced as fast as possible. Just as soon as the air compressor was in place the air pipes were connected up and the wells tested before the discharges were extended to the receiving basin. One well was found with a deposit of sand in the bottom reaching 5 feet above the foot of the discharge pipe Several unsuccessful efforts were made to force air into this well. The river having receded, the air pipe was disconnected at the top of the well and a 3/8-inch gas pipe coupled and lowered. It stopped 5 feet from the bottom. It was churned a few minutes and soon went down the remaining 5 feet. Again the air pipe was coupled and the air pressure increased to 90 pounds per square inch. The effect was almost startling, but gratifying. The obstruction was cleared out very quickly. No other system of pumping could possibly have accomplished the clearing out of this well of the sand deposit.

The discharge and air pipes to each well are independent. That is, each well has a separate discharge to the receiving basin and a separate air pipe from the receiver. These are carefully graded and are not exposed at any point except where the discharges pass through the top of the walls of the receiving basin, and have open discharge.

The power house is a good substantial brick structure immediately alongside the Ohio River Railroad. It contains the steam boilers, a 200 horse-power Corliss engine, electric dynamos, air compressor and forcing pump. These are all placed on separate and substantial foundations. No machinery is attached to the walls of the building. All the machinery, both pumping and electric, is belt driven from friction clutch pulleys on a line shaft. All the machinery is very substantial and capable of performing its duty without strain. The air compressor is 14 inches diameter by 18 inches stroke, with mechanically operated valves. It is speeded to 96 revolutions, and has a capacity of 312 cubic feet of free air per minute. The required working pressure is from 45 to 50 pounds, varying with different river levels.

The discharge of water is not constant, however, but irregular or intermittent, as though the air and water formed alternate strata or volumes within the discharge pipes. It varies with the depth

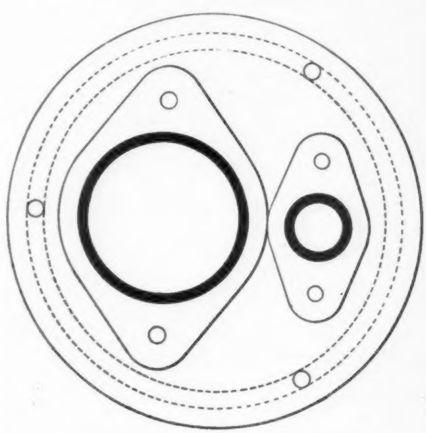


FIG. 3.—CAP AND GLAND FOR WELL HEAD.

of water in the river, ranging from 1 volume of water to 8 volumes of free air to 1 to 6. As the river is constantly rising and falling and frequently is 25 to 40 feet deep over the wells, the pressure on the sand surrounding the wells is constantly changing and affects the capacity of them as well as the necessary air pressure to pump them.

The reservoir is situated about 1½ miles distant and at 225 feet elevation. It is built of vitrified paving brick laid in Portland cement with 18-inch concrete bottom and roofed over with slate. Water is taken from the receiving basin by belt driven triplex outside packed plunger pumps, 9 inches diameter by 12-inch

stroke, operated at 37 revolutions per minute, delivering about 22,000 gallons per hour.

As there is no demand in the town for electric current during the day, the works are operated at night only. Usually the air compressor is operated one night, and the following night the forcing pumps. The water received the previous night in the settling or receiving basin has about 12 hours to become cleared of any sand brought with it from the wells before going to the reservoir. This basin has a capacity of about 225,000 gallons; the reservoir about three times this quantity. The construction of the receiving basin is the same as the reservoir. The engine has ample power to operate all the machinery at the same time. Two men only are required to attend the combined plant. The entire plant, including power house, lot, reservoir site, rights of way, mains, hydrants, wells, lines, machinery, arc light, all included, cost $55,000. In addition to the public and private consumption of water, two busy railroads are consumers. All customers are served by meter and therefore there is practically no waste.

There can be no doubt that water taken by air in this manner is purified to some extent, the admixture of air serving to oxidize and destroy organic matter. Samples of the water taken last January are still bright and sparkling, have no odor and remain apparently unchanged. There probably is not another town of 5,000 inhabitants in the country that has a better or more complete combined water and light works. Certainly there is not another town of any size on the banks of the Ohio River from Pittsburgh to Cairo that has better water, if as good.

The works have been in constant operation since January last and have been visited by many interested parties. The system demonstrated at Point Pleasant will beyond doubt be repeated elsewhere. That it is regarded as a paying enterprise we have but to repeat the president's statement made to the writer a week ago, "There is no stock for sale, and not a single share was sold at less than par." The pump and compressor were built by the Stilwell-Bierce & Smith-Vaile Company, of Dayton, Ohio.

What has been accomplished at Point Pleasant can be done at hundreds of other small towns similiarly situated where there is no water works. Here it has been demonstrated that bright, sparkling water can be obtained from a muddy, filthy stream without the use of chemicals or mechanical filters.

Just use the filter nature has so abundantly supplied at the bottom of such streams, and by proper arrangement of the pumping system combined with an electric lighting system, thus economizing the operating expenses to a minimum, establish first-class water and electric service on a paying basis when neither separately would pay operating expenses.

The air lift system is undoubtedly the simplest as well as the best of all known methods of serving such towns with good water. Nor is the system less applicable to larger towns, as well as to factory and domestic supply.

Artesian wells, or wells supplied from land sources, generally yield hard water or water highly charged with mineral salts. The water at Point Pleasant is soft, pleasant and wholesome. The railway companies using it speak very highly of it. It is simply Ohio River water freed of filth and all objectionable matter that renders it so disgusting at many towns along the stream.

CLARK HOWELL,
in "The Metal Worker."

The Sargent Gas Engine Oiler.

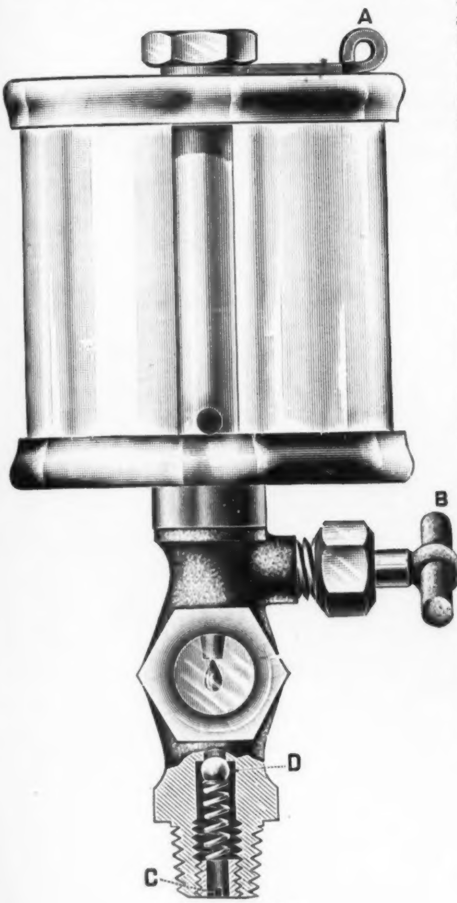
The proper lubrication of the cylinder and piston of a gas or oil engine in which the average temperature during inflammation is not far from 2000 deg. Fahrenheit, is one of the essential conditions of successful operation.

In order to obtain the best results, a constant feed commensurate with the piston speed is absolutely necessary, as too much oil will cause smoke and too little a cutting of the cylinder or piston.

Then, with a variable speed, as in automobile engines, the amount of oil should be in proportion to the revolutions and should stop when the engine stops, and to attain such results the feed must depend on some factor of the speed such as the induction strokes of the engine.

Fig. 1 illustrates an oiler which has many excellent features. This oiler was designed especially for lubricating the

cylinders of gas or oil engines, vacuum pumps or air compressors in which the pressure during the induction stroke is slightly below atmospheric pressure, which is always true of such machines, for if the pressure within were not less than without, the cylinders would never fill. The essential features are a glass reservoir which is filled through a hole in the top normally covered by the slide



GAS ENGINE OILER.

A.; B., a needle valve which adjusts the feed into the air-tight bullseye, as shown; and D., a check valve held to its seat by a spring, the compression of which is adjusted by the nut C., which can be turned with a screwdriver.

While this is essentially a cylinder-oiler, by removing all compression from the spring, it may be used in place of the ordinary sight feed oiler on any other part of the engine.

When this oiler is used for admitting oil to the cylinder of a gas engine or air compressor, the check valve spring is so adjusted that the valve seats when the air pressure above and below the check is the same, but if the air pressure below the check valve is rarefied or slightly reduced, the check will open and allow the air in the bullseye enclosure to pass into the cylinder, whereupon the atmospheric pressure on the oil in the reservoir will force it down through the needle valve to the bullseye chamber, from which it will pass into the cylinder every time the check valve opens.

When the engine stops, rarefaction in the cylinder ceases, the check valve remains seated and the oil stops feeding through the needle valve, because oil cannot drop into the bullseye chamber if air and oil are not drawn out.

When compression begins in the cylinder, the check valve shuts and no smoke or pressure from the explosion passes into the bullseye chamber or reservoir.

The reservoir can be filled while the engine is stopped or running without opening or closing a valve or changing the adjustment of feed.

The quantity of oil is always in sight; the amount feeding can always be seen; the oiler stops with the engine and begins when the engine is started again, and as no pressure accumulates in the glass reservoir, there is no danger of the oil cup exploding.

This oiler is the invention of Mr. C. E. Sargent, and is manufactured in several sizes by the Michigan Lubricator Co., 266 Beaubien Street, Detroit, Michigan.

Air Surface Condenser.

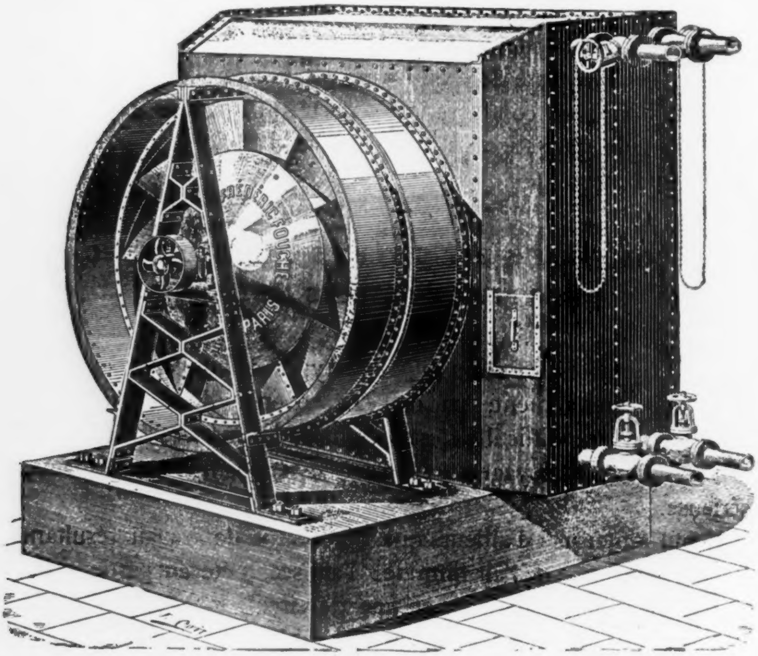
A very interesting pamphlet has recently been issued by Mr. Fred Fouche, of Paris, who exhibited an apparatus showing a new method of condensation for creating a vacuum in the exhaust of steam engines, the condensation being practically on the same principles as is now, and has been, effected in surface condensers, with the exception that instead of using cold

water for condensation purposes cold air takes the place of same.

Mr. Fouche had one of these installations at constant work at the Paris Exposition, and claims that his apparatus would be of great value if adopted in places where fuel is expensive, where water for condensation cannot be obtained, or in case condensation water would contain lime or other foreign material which would be detrimental to the effectiveness of a surface condenser.

In addition to the above apparatus, a motor, or engine, and a fan are required to transmit a current of cold air between the different sections of corrugated plates containing the exhaust steam of the engine, or engines, this current of air to be sufficient for condensing the exhaust steam from the main engine.

From tests made by the inventor, he does not claim to obtain as high an efficiency as that of surface or jet condensers, but he claims to come to within 3 to 5 per cent. of the actual efficiency now obtained by the above, and maintains that such a new departure in the line of condensers for stationary engines or locomotives should be seriously looked into by investors, who desire economy and dividends accruing therefrom.



AIR SURFACE CONDENSER.

The apparatus which Mr. Fouche is placing on the market consists of a surface condenser consisting of narrow exhaust steam spaces between corrugated iron or steel plates, having a great condensation surface, instead of tubes, as generally used in surface condensers. He claims that by adapting this method he can obtain a greater condensing surface with a lighter weight and lesser cost.

It is a well-known fact that a locomotive consumes from 5 to 7½ lbs, of combustible per horse power per hour, and if

a condenser could be adapted to same and create a vacuum of only 20 inches per sq. in., a benefit or saving in fuel and water consumption, varying from 15 to 25 per cent., would be effected.

Taking the above data into consideration, Mr. Fouche makes the statement that the weight of an air surface condenser, with its fan and engine, will equal about the weight of water and coal saved in a two hours' run of an ordinary passenger train running at a speed of 40 miles an hour, and, in addition to that, make a saving of an average of 20 per cent. of the amount of coal used for the engine.

Taking as a basis that a locomotive develops on an average only 500 H. P., which is low, as the Empire Express develops at times as much as 1,400 H. P., and rating the coal consumption at six pounds per horse power per hour, we figure that a saving of 600 pounds of coal per hour could be effected, not counting the saving in water consumption.

The reader will understand, of course, that for adaptation on railroads the condensing apparatus would have to be placed on a special auxiliary tender.

This matter, we think, should be of interest to any railroad company, as the question of fuel is so important at the present time that it cannot be overlooked.

The inventor, in his pamphlet, omits to mention the weight of the condenser to suit a certain horse power, nor does he give the number of sq. ft. of cooling surface he would suggest per pound of exhaust steam at atmospheric pressure.

Should any reader be interested in the subject we will be pleased to obtain any information we can in the matter.

Hand Versus Air-Riveting Power.

Actual Cost Compared with Hand Work in the Field for the Erection of New Work and Repairing; also, Drilling for Reinforcing Old Spans.

COMMITTEE REPORT.

To the President and Members of the Association of Railway Superintendents of Bridges and Buildings:

As chairman of this committee I enclose letters received from Messrs. F. S. Edinger, S. P. Co., and O. J. Travis, I. C. R. Co., relating to this question, which I believe is of interest to all; personally I am only able to give at present my experience in this matter, viz.:

Since 1890 this company has been steadily replacing all wooden and combination truss bridges with steel, and up to May, 1899, all riveting in field had been done by hand; since May, 1899, we have erected 22 new steel spans of various lengths, aggregating in all 2,455 lineal feet; besides this we have repaired several old spans taken down, reinforcing, changing floors, raised to safe clearance, etc. In doing this we have used pneumatic tools for riveting, chipping, drilling, reaming, etc.

In the erection of the 22 new spans record was kept of the number of rivets driven, viz., 80,065. In the repair work we did not pay as close attention to number driven, but there were a large number.

With pneumatic riveting hammers I find two men and one heater can average daily (10 hours), 500 rivets, whereas by hand 250 rivets per day was a good day's work (more often less), for three men and one heater. One day we drove 700 rivets, by using an additional man to take out fitting-up bolts, etc. This was the work of one air hammer only.

In inspecting rivets I find the work far superior to hand work—less loose rivets, heads invariably perfect, shank of rivet filling hole, and in every way far superior to hand work done by our men, or by others in the past; also work can be done readily in places where great difficulty has been experienced with hand tools.

It seems useless to call attention to the benefit of reamed holes in assembling joints made by pneumatic drills over the "drift-pin work," so much in use, where hand riveting prevails; but with the rapidity that air drills run, the expense of reaming rivet holes has been reduced to a minimum.

The pneumatic plant in use on this road for bridge work consists as follows:

One 12 H. P. Fairbanks, Morse & Co. combined gasoline engine and air compressor.

Two galvanized iron water tanks.

One galvanized iron gasoline tank.

One boiler iron main reservoir, "large."

One boiler iron auxillary reservoir, "small."

All necessary fittings, etc., and mounted on box car, one No. 2 Boyer pneumatic hammer, old style; two New Boyer 000 1 6-16x5 inches, pneumatic hand-riveting hammer; two hand steam drills (running

them with air), with necessary hand, spring, and air dollies, rivet snaps, forges, drill bits, reamers and other small tools necessary to this class of work.

The 12 H. P. gasoline engine and air compressor furnishes more than enough air to operate all of our tools at the same time. By using the small reservoir at bridge and main reservoir on car, and operating at 90 pounds pressure, we have had in use at one time three hammers, two drills, two heated forges, and one blacksmith forge, and have been able to get full capacity out of all of them. We have now ordered additional tools, as we find we have sufficient power to operate them, especially when cutting out the old steam drills.

In starting we obtained one No. 2, old style, Boyer hammer, which had been in use by another department; this hammer we repaired, and in "Cost of Plants," referred to later, we have valued same at half price after repaired. Bought two 000 New Boyer hammers, 1 516x5, and last month we ordered a No. 2 Boyer piston drill and a latest improved New Boyer long-stroke hammer; this hammer and drill I have seen in actual service, and think they are as near perfect as it is possible to get. In using these hammers we find they are free from vibration or concussion that had been somewhat of a drawback to pneumatic hammers I have noticed in the past. We use hand riveters only in field work on bridges, as we have not driven over 7/8-inch diameter rivets, and think in such class of work it is more economical than a yoke riveter. In handling larger rivets, repairing or rebuilding work done in yards or shops, a yoke riveter could be worked to good advantage. In field work there were many difficulties when doing hand work that would cause delays that are now overcome quickly by use of air. In chipping, cutting out, reaming, drilling, etc., work can be done in a fraction of the time that it used to take, and when done you have a good, presentable piece of work; in fact, I consider pneumatic tools are so far ahead and superior to hand work in everything that it is practically unnecessary to dilate their uses.

It costs us the same to spur out at bridge site, as we always spurred out when running a hand gang, and by increasing pipe line we can invariably find a good location for the outfit cars with small expense.

In putting in staging or falsework for riveters we find the cost is less, and by doing the work faster by air enables slow orders, or delays to movement of trains, to be reduced, and the slowing up or stopping of a train as an item of expense to railway companies.

For your information I have compiled some data on this question, showing actual cost of work. We will take up first cost of pneumatic plant. In explanation, would state, I only show increased cost of plant that, in both hand or air, work tools in common; that is, forges, dollies, chisels, snaps, and all such tools, do not appear in this comparison, as one practically offsets the other.

Cost to company for air compressor, reservoirs, machinery, water tanks, hose and fittings, mounted on car	$1,073.00
Three hammers and two steam "air" drills	627.00
Total cost of plant	$1,700.00

Cost to maintain since May, 1899:

Repairs to combined engine and air compressor	$34.00
Repairs to new hammers	6.30
Repairs to old hammer and drills	9.00
Total cost of repairs	$49.30

Proportion of cost of plant chargeable to work per day, on basis of 20 per cent. depreciation per year:

Twenty per cent. of 1,700=per year $340, or per day basis, 313 working days equals year, $1.09.

Cost to maintain since May, 1899, $49.30,
Or per month, 1-17th of $49.30=$2.90,
Per day, 26 days to month, 11 cts.

Cost to operate gasoline engine and compressor per day:

Fifteen gasoline, at 11 1-5 cts	$1.68
Oil, waste, etc	.12
	$1.80
Total cost to operate plant per day	$3.00
On basis of running three rivet hammers and forges equal cost for one hammer of	$1.00
Oil for hammer, estimated amount per day	.12
Labor two men, at $2.40 per day	4.80
Labor one man, at $2.20 per day	2.20
Total cost to operate one hammer per day	$8.12

Cost of riveting by hand (as noted on commencement of this detail, there are no charges for tools, as the small tools, forges, etc., not shown in riveting by air, practically offsets tools in riveting by hand):

Labor two men, at $2.40 per day.... $4.80
Labor two men, at $2.20 per day.... 4.40

Total cost of hand-rivet gang per day.. .... $9.20

Men with pneumatic riveter will average 500 rivets per day for $8.12, or per hundred, $1.62.

Men with hand power average 250 rivets per day for $9.20, or per hundred, $3.68.

The above figures demonstrate that it costs more than double to drive rivets by hand than by using pneumatic tools.

Another point when you have a compressor outfit, when rebuilding old bridges, by putting in a sand blast you are able to eradicate all rust spots that you will find in all cases on old iron, which it is practically impossible to do by hand. This leaves iron in perfect condition to receive paint, and you then know that rust spots have not been hidden under a coat of paint.

In closing, will state I think the amount invested in a good pneumatic plant is one of the best investments a railroad can make, especially now that steel structures are so much in evidence on all first-class roads.

A. B. MANNING,
Chairman Committee.

I am very much interested in the subject "Hand vs. Air Riveting Power Used," and am glad of the opportunity to exchange ideas and experiences with others who are using pneumatic tools in field work.

At present we have two complete pneumatic plants in the field, each consisting of a 12-horse-power gasoline driven compressor and tools. The first plant which we purchased consisted of one compressor, two pneumatic yoke riveters, two pneumatic riveting hammers, and two air drills, one of which was fitted with angle gear for getting into corners not accessible to the drill proper.

The first work done with the pneumatic tools was a cover plate job on a 200-feet-through iron span, which required the drilling of about 6,000 holes 15-16 inch diameter through ⅜ inch to ½ inch of metal.

Including the cost of setting up the plant for the first time, which was unusually great owing to the inexperience of all hands, the work was done with a saving of about 25 per cent. on the cost of doing the work by hand.

We found that the yoke riveters answered the purpose very well in riveting cover plates and other straight work where, when once suspended, they would reach a number of rivets, but they were great time consumers when it was necessary to move frequently.

The riveting hammers which were quick acting and short stroke did not give good results—the blow being too light to upset the shank of the rivet to fill the hole, and the concussion of the hammer was very distressing to the operator.

We have since secured hammers which have a long, heavy stroke with which we get satisfactory results as to the quality of the work, and the effect on the operator is not injurious.

We have two plants in use at the present time.

The one used by the steel bridge erecting gang consists of the following tools:

One 12-horse-power gasoline driven air compressor.
Five long-stroke pneumatic hammers.
One pneumatic yoke riveter.
One pneumatic clipping hammer.
Two pneumatic drills.

Together with the usual complement of forges and holding-on appliances used in hand riveting.

The yoke riveter holds as well as drives the rivet.

With the long stroke hammers we use the usual suspended dolly-bars, spring-dollies, or lever-dollies, as may be best suited to the condition—the same appliances as would be used were the rivets to be driven by hand—and no more difficulty is experienced in holding the rivets up to the work than were they to be driven by hand. The hammers upset the rivets well into the hole and the heads are very much better than can be made by hand, in fact nearly all heads are absolutely perfect.

Two men and a heater form a riveting gang, and they drive double the number of rivets per day than the gang of three men and a heater where driven by hand.

Where there are a great many rivets of one length to drive, as in lattice girders, water tanks, etc., we use a portable fur-

nace with an air blast, and one heater supplies two riveting gangs with hot rivets.

The amount of staging required, from which to drive rivets with pneumatic tools, is very much less than is required for hand riveting, as it is only necessary to provide seats or standing room for two men, for which oft-times a single plank suffices. In riveting viaduct towers, laterals in spans, etc., where there are only a few rivets to be driven in a place, the saving on erection of staging alone is a very considerable item.

We now have the air compressor set up in one end of a 50-foot standard tool and material car which, in addition to carrying the compressor, receivers, circulating tanks, and pneumatic tools, serves to transport other tools and rigging from one bridge to another.

We use a Wharton climb-over switch, which is dropped between the rails temporarily, and the car is spurred out on a temporary track, as near to the work as is practicable. This saves the expense of handling and setting up the plant on the ground for each bridge, and is much cheaper.

With plenty of storage room for compressed air, so that the pressure will not run down suddenly, we can operate five riveting hammers at once, with a 12-horse-power compressor or two drills and two hammers without reducing the pressure to less than 75 pounds.

The drills use a great deal more air than the hammers from the fact that they run uninterruptedly, while the hammers when driving 50 rivets of ⅞-inch diameter per minute are using air only about 5 per cent. of the time, which gives the compressor a chance to catch up.

We have a storage capacity of about 80 cu. ft., and I think we could use one or two more riveting hammers by increasing the capacity of our compressed air receivers, as the compressor is frequently cut out by reason of the pressure being at maximum (90 lbs.) and the relief valve open.

With pneumatic tools a great many rivets can be readily driven in places which would be inaccessible to hand tools, from the fact that a rivet can be driven where there is room to insert the hammer, which is about 20 inches long.

The chipping hammer is frequently useful in trimming and capping, and with it all anchor bolt holes in masonry, up to one inch diameter, are drilled by simply inserting an × pointed drill and holding it up to the work. Larger holes are drilled with the heavier hammers. There is a saving of about 25 to 40 per cent. over the cost of hand work in drilling these holes.

In fitting up the work ready for riveting, a reamer is used in the drills, which one man readily handles, and with which all mis-matched holes are reamed, and which insures a full bearing for the rivet and does not burr and separate the plates as is the case where drift pins are used. This, while perhaps not reducing the cost very much, improves the character of the work.

We also use the air drills for boring all bolt holes in bridge floor timbers by inserting an auger in place of the drill. This results in a saving over the cost of hand boring of about 50 per cent., which could be further increased, I think, by using the pneumatic boring machines, which run at higher speed and are more convenient to handle.

The cost of fitting up and riveting on new steel bridges (all rivets ⅞-inch) averages to date 35 per cent. less than if the work had been done by hand for all work done since we have had the pneumatic tools in use. Work now being done with pneumatic plant costs 40 per cent. less than hand work, and we expect to still further increase this percentage as the men become more expert with the tools.

The character of the work is much better than we have been able to do by hand.

In case the work is of too great magnitude for one plant, we install both compressors and combine all of the tools, but usually one plant is sufficient. When not engaged on bridge work we use our second plant in the erection of steel tanks and in timber work, such as cofferdams, grillages, slip sheathing, etc., where there is a great deal of boring to do. In the erection of steel tanks we use the yoke riveter. For the horizontal seams the yoke is hung on rollers which roll on the top edge of the sheet, and for the vertical seams the yoke is suspended by means of light differential pulleys which allow of adjustment of the yoke to the proper height. The chipping hammers are used for calking.

The saving in pneumatic over hand work on a 60,000 gallon tank is about 25 per cent.

My experence with pneumatic tools has demonstrated to my entire satisfaction that all work to which they are applicable can be done much cheaper and also much better than by hand.

P. S. EDINGER,
Member of Committee.

With reference to comparison between hand riveting and air machine riveting and drilling, I would say this is a subject where I would consider comparisons odious. I have had one 12-horse-power and one 22-horse-power gasoline compressor at work. The former for nearly two years, the latter for nearly a year on various kinds of work; reinforcing, drilling, riveting, and chipping, both in the field and shop. All air work has been done with a most satisfactory measure of economy over hand work. We have done over five or six times as much drilling with a like number of men as we were able to do with rachets, and in places inaccessible to hand rachets, we do over twice to three times as much riveting with air as we can do by hand, and do the work 50 per cent. better. In fact, I cannot say too much in favor of the air machines. They are all that could be desired.

I may add, however, that I have substituted the latest patterns of hammers as fast as they have been improved, and with the best results.

O. J. TRAVIS,
Member of Committee.

—Age of Steel.

Notes.

The Standard Pneumatic Tool Company has just received an order from the Navy Department for twenty pneumatic hammers and eight drills. They will be operated at the Brooklyn Navy Yard.

Mr. E. F. Senfft, Commercial Manager of the Mannesmann Tube Works and a member of the Dusseldorf Verein, has just arrived in this country on a visit of some duration, to inspect various American manufacturing industries.

H. K. Porter, of the Porter Locomotive Works, of Pittsburg, returned from Europe on the St. Paul. Mr. Porter said that the American iron and machinery trade abroad is making great inroads in England and on the Continent.

The Westinghouse friction draft gear which is to be built by the Westinghouse Air Brake Company, in their shops at Wilmerding, Pa., is expected to facilitate the hauling of longer and heavier freight trains. It is expected there will be a very heavy demand from the railroads for this type of gear.

The McKiernan Drill Company, 120 Liberty Street, New York City, is reported to have secured a location at Dover, N. J., to manufacture its machinery. T. E. Sturtevant, of Dover, has resigned his position with the Morris County Machine Company, and will be superintendent wherever the McKiernan company locates.

The volume of compressed air delivered at sixty pounds pressure at an elevation of 10,000 feet is 72,7 per cent. of the volume delivered at the same pressure by the same compressor at sea level. A compressor which, at sea level, would supply power for ten rock drills, would, at an altitude of 10,000 feet, furnish air for only seven drills.

It is impossible to deny that the American compressed air system is gaining ground, and that except in England and on railways abroad which are under the control of Englishmen the vacuum is gradually disappearing. Whilst the American claims that his brake is the best in the world, the Englishman is content to reply that his own is good enough.

Mr. Thomas A. Edison has just perfected a new device for heating compressed air which, he asserts, at the same time utilizes all the store energy of coal and obtains fully 95 per cent. of it. "My invention," he says, "is a device for heating compressed air so that the losses in compression and utilizing as power are not only made up, but that it is possible to get power through air compression for less coal per horse power than through the steam engine."

The Librarian of Congress, Washington, D. C., writes that he is very anxious to complete the files of Compressed Air, and we will appreciate it very much if any of our subscribers who have no use for the following numbers will return them to us in order that we may forward them to complete the files of the Congressional Library:

Vol. I.................5. 6, 7, 8, 9, 10, 12
Vol. II..................1, 2, 3, 5, 6, 7, 8
Vol. III..........................2, 3, 4

Injections of cement have long been employed for stopping cracks in masonry; but the operation has been performed from the surface to the inside. The "Annales des Ponts et Chaussees" mentions the following method devised by M. Camere, who works the reverse way. He makes vertical channels in the new masonry, 12 centimetres in diameter, into which cement is injected by the aid of air under a pressure of 1 kilogramme per cubic centimetre. The system can, it is stated, be applied for the consolidation of masonry in bad condition.

At 6 a. m. on October 28, the first half of the low-pressure pneumatic interlocking plant now being installed at the Grand Central station yard, New York City, was put in service. This part includes all of the outbound tracks and the outlet from the storage track on the west side of the yard. The change from the old to the new system was made without the least trouble, and so far there has not been one failure of any of the new mechanism or a single minute of delay to trains. The Standard Railroad Signal Company are justly proud of this installation.

It is highly desirable that air intended for compression should be admitted to the cylinders at as low a temperature as possible. For the relative increase in temperature during compression is less the cooler the air is. Thus if any given volume is compressed without artificial cooling to 21 atmospheres (about 300 pounds) its volume will be about one-tenth that originally occupied. If we start with an initial temperature of zero the total increase during the operation will be about 650°. If we begin at 60° the increase will be 800°, and if we begin at 100°, the increase will be 900°.

When pure, air is a mixture of the two elementary gases, oxygen and nitrogen, in the proportion of about 20 per cent. of the former to 80 per cent. of the latter. It always contains, however, a small and varying quantity of vapor of water, and several other gases. When condensed into liquid form, these impurities are practically eliminated. When allowed to return again from the liquid to the gaseous state, it is found that the nitrogen evaporates more readily, so that by a proper arrangement of apparatus it is possible to produce from the substance two products, one of which is nearly pure nitrogen and the other nearly pure oxygen.

An interested crowd gathered around the Tripler Company's booth at the automobile show in the Grand Central Palace, New York. For the first time in public, a demonstration was given of the workings of the new liquid air machine on exhibition there, and a good-sized body of spectators were present. The charging of the machine took about fifteen minutes, and then, with a ripple of applause, the vehicle glided out onto the track. It ran slowly at first, with gradually increasing speed. The most noticeable thing was the smoothness and silence with which it worked. It is claimed by the makers that liquid air can be produced at a cost of less than two cents a gallon, and that the cost of running the machine is less than seven-eighths of a cent a mile.

The latest device for economizing fuel in steam furnaces has been brought forward by Professor Linde, the first man to put the industry of cold storage on a commercial basis. Professor Linde has lately been giving his attention to the industrial production of liquid air, in which he has been fairly successful. The liquid air can be supplied in any required quantity, but the uses to which it can be profitably applied have not developed in the same proportion. Professor Linde now proposes to employ liquid air in conjunction with coke or inferior fuel in steam boiler furnaces. It is stated that after giving off the nitrogen, a gas remains that consists of 50 per cent. of oxygen, that can be profitably used in boiler furnaces at the present high price of fuel. The idea is distinctly novel; and probably, but for the distinction attached to Professor Linde's name, would attract little attention.

For obtaining an exact idea as to liquid air there is a very simple method, in the opinion of M. Robert Pitaval, who makes this observation in "L'Aluminum," and that is to consider it as the extreme limit of compressed air, when one can easily conceive that it may be employed as a refrigerating agent, as motive power, and as explosive force. Again, its composition sufficiently indicates that it may be a source of oxygen which, as is well known, has many uses; but the success of all these applications depends upon a principal factor, which is the sale price, and consequently the cost price of liquid air. This substance may, in fact, serve to afford liquid oxygen owing to the differences of volatility in the ewo elements which compose it. By evaporating one-half a given mass of liquid air a concentration of oxygen to 85 per cent. is obtained, and, on pushing the evaporation further, nearly all the nitrogen may be eliminated.

Mr. Asa M. Mattice has been appointed Chief Engineer of the Westinghouse Electric and Manufacturing Company, and will enter upon his duties in December. Mr. Mattice was for ten years up to a year ago principal assistant to E. D. Levitt, of Cambridgeport, Mass., and has been actively connected with the design of all the large machinery coming from Levitt's office during that time. During the past year he has been remodeling the Cocheco Cotton Mills at Dover, N. H. Mr. Mattice is an engineer graduate of the Naval Academy of the class of '74, of which class Mr. B. E. Warren, Vice-President of the Westinghouse Electric and Manufacturing Company, is also a member. He was assistant to Admiral Melville at the beginning of the new navy; and had an important part in the design of the machinery of the "Maine," "San Francisco" and others of the important early ships. The Westinghouse Company is to be congratulated on the additional strength which he will give to their already strong engineering staff.

To supply compressed air for the construction of one section of the New York tunnel or subway, a steam plant has been erected at the north end of Union Square on Seventeenth street at a cost of nearly $100,000, including the air piping to the rock drills and other machinery along the section. The plant which is erected in one side of the street proper will contain five boilers in batteries of two and three. The boilers are of multi-tubular type, 60 inches by 16 feet, set in permanent brick settings with two steel smokestacks about 70 feet high. The plant also comprises two large air compressors, a blacksmith shop, small machine shop and storehouse for various tools. It is rather surprising to see a power plant erected in such a permanent manner right in the street of a large city, and for an apparently ephemeral job, but as the construction of this section may require two or three years, the expenditure for power purposes will undoubtedly be a good investment, as compared with the cost of power generated by small portable boilers generally used in work of this character. To avoid smoke and cinders coke is used instead of coal.

The Paris Omnibus Company has decided to abolish horse traction on its lines from Passy to the Hotel de Ville, from Muette to Rue Tailbout, from Montrouge to the Gare de l'Est, and from Auteuil to the Madeleine. Compressed air motors are to be used, and a compressing plant of from 5,000 to 7,000 horse power installed at Billancourt.

The air will be stored in the main receivers at a pressure of 1,400 pounds per square inch, and will be distributed to the charging stations by pipes laid along the roadways. These pipes are weldless steel, and vary from 2-inch up to 4-inch in diameter. The pipes are made in lengths of 64 feet in order to reduce the number of joints at which leakage may take place. The cars have two decks and will seat 52 passengers. The air is reheated in small coke stoves before being passed into the motor cylinders. There are eight air receivers on each car, having an aggregate capacity of 88.27 cubic feet, which is sufficient for a run of 7½ miles at least. The pressure in these reservoirs is 1,137 pounds per square inch, and less than three minutes is needed to charge them.

John B. Smith & Sons, Toronto, have installed an equipment of compressed air hoists in their saw mills and lumber yards, ranging in capacity from ½-ton up to 4 tons. So far as can be ascertained this is the first application of this mode

of handling lumber in Canada. Since its inception a great saving has been effected. For example, an ordinary load of lumber can be loaded or unloaded by two men in from 20 to 40 minutes less time than formerly. In handling the heavy lumber arriving in their yards by trains, less men are required, and a system of overhead tracks permits the lumber to be put right alongside the machinery in the mill, with the one handling. In a plant of this kind the fuel being so plentiful the first cost is almost all to be considered. The air is compressed in the ordinary way, and is stored in a central tank, and distributed to auxiliary reservoirs. The rubber hose used is coupled at convenient points with automatic valve couplings, which permit of the hose being detached, and as soon as this is done the valve prevents any loss of air, thereby the hoist retains its load for any length of time necessary for its removal to other parts of the yard or building by the trolley overhead.

Raising sand from the ground floor to an overhead bin by compressed air is done at a great many railroad engine houses, but blowing it upstairs with a fan blower is not very extensively practiced.

At the Pennsylvania Railroad engine house, in Louisville, Ky., General Foreman Foster uses an old 40-inch fan blower for this work. A smaller blower would do the work, but as he had this one on hand it was installed. A 6-inch galvanized-iron pipe leads from the fan in engine room through the sand house to an elevated bin about 30 feet high. The sand flows from the bin under the sifting platform through a 1¼-inch pipe into the 6-inch air pipe, where the current of air takes it up the pipe, which lies at an incline of about 30 degrees, into the bin. The end of the sand pipe is curved to point the same way the current of air is traveling, so that the air does not blow up through the sand into the sifting bin.

At the top of the storage bin there is a pipe, 8 feet high, 12 inches in diameter, through which the air escapes. All the sand drops in the bin, while the loam and dust are carried out the ventilating pipe. Something over a ton an hour can be handled by this method. It is a continuous operation as long as the sand is running into the air pipe.

The fan is run only while the sand is being sifted into the lower bin, and it will not run into the air pipe unless the fan is running. The current of air seems to draw it through the curved nozzle.

Sand is taken from the elevated bin into the engine sand boxes through a pipe, the usual way.—Locomotive Engineering.

A meteorologically interesting experiment is described by H. Ebert and B. A. Hoffmann. If a metal is suspended by a cocoon thread in liquid air, and then withdrawn, it will prove negatively electrified. The nature of the metal is immaterial; the authors noticed, in fact, that wood, glass, sealing wax, etc., all became negatively electrified. No electrification results, when the air is filtered, and is, therefore, free of floating particles of ice. If, on the other hand, the metal is rubbed, simply by making it glide up and down, against the hoar frost which begins to form quickly over the liquid air, when it is kept in an ordinary beaker, the electrification will be very strong. These experiments demonstrate that the electricity is due to the friction between the ice and the suspended body; the ice assumes a positive charge. A frictional electric machine can be based upon this observation. When a piece of amalgamated copper wire gauze is placed in a glass tube, through which liquid air is passing, the wires will prove negatively charged, as long as the current of air is maintained, because the air will always carry some frozen moisture with it. The ice is the essential thing; but the air is wanted for two reasons, to freeze the water and keep the ice very cold and very dry. That dry cold ice is easily electrified by friction was known to Sohncke, who made use of this observation in his theory of thunderstorms of 1886. The presence of dust in the atmosphere will facilitate the formation of ice particles and friction with them, and we know from balloon observations that clouds of ice needles really exist. That this friction plays an important part in the generation of atmospheric electricity has more than once been suggested; but so far we had no striking demonstration of this electri-

fication. The observation further teaches that electric experiments, in which liquid air is used as cooling agent, may be misleading.

Compressed air baths are the latest things in health restorers.

One step further, and the fashionable cure will be taken in the Greathead compressed air shield at the "working face" of the newest Thames tunnel, wherever it happens to be.

It is at Reichenhall, in the Bavarian highlands, that this newest invention is being applied to the cure of asthma, bronchial catarrh, and numerous other forms of disease. The bath is constructed on very similar lines to the diving bell. The pneumatic chamber is built to accommodate from three to twenty persons, and can be either round or oval. The outside resembles more than anything else the turret of a modern man-of-war. Small windows with very thick glass panes let in the light, and the heavy iron door when closed is completely air-tight. The air admitted under pressure passed into a hollow space underneath the chamber and up through the carpet, which is placed over a perforated metal plate. This prevents any draught being felt, even when the pressure is at its greatest. The foul air is carried away by means of two pipes with openings immediately below the cover of the chamber. The inside is furnished with cane armchairs and a table, and the patients pass the time either in reading or writing, or very often in sleeping.

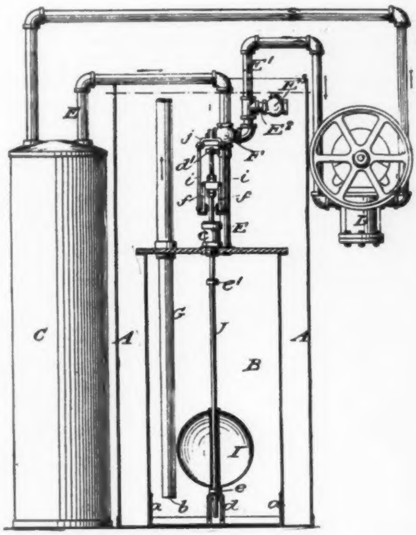
Each sitting lasts about an hour and forty-five minutes; and during the first twenty-five minutes the pressure of the air is gradually raised by means of pumps till it attains 30 centimetres. This is maintained for forty-five minutes, and then the normal pressure is gradually restored. The chief sensation during the sitting (says the Times in describing the process) is a slight pain and discomfort in the ears, but this soon passes off, and can, moreover, be greatly diminished by filling the ears with cotton wool. For a beneficial and lasting result at least 30 sittings are required, and then a complete cure is very often effected.

The idea was tried as long ago as 1832, but they did not succeed then in maintaining the purity of the air under pressure.

PATENTS GRANTED OCT., 1900.

Specially prepared for COMPRESSED AIR.

658,941.—APPARATUS FOR RAISING LIQUIDS. James Clayton, New York, N. Y. Filed Sept. 23, 1898. Serial No. 691,687.



In an apparatus for raising liquids, the combination of a pressure-tank provided with valves for controlling the entrance of liquid thereinto and with a liquid-discharge conduit, a reservoir for compressed air or gas, a pipe between said reservoir and tank for the passage of the compressed air or gas from said reservoir to said tank, a compressor for supplying the compressed air or gas to said tank, a pipe branching from the first-mentioned pipe and constituting the suction-pipe of the compressor for returning to the compressor the spent air or gas from the tank, a three-way cock at the branching of said pipes, an arm on the spindle of said cock, a float in the pressure-tank, a rod actuated by said float, a tumbler-lever and an independent fixed fulcrum therefor, connection between said tumbler-lever and rod and between said lever and the arm on the cock-spindle, an inlet from the atmosphere to said suction-pipe and an outwardly-closing check-valve at said outlet.

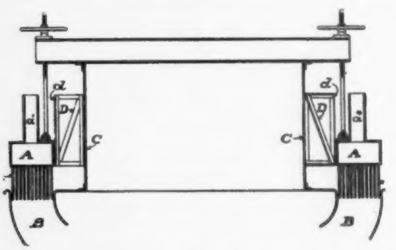
659,210.—PNEUMATIC ORGAN. Melville Clark, Chicago, Ill. Filed July 15, 1899. Serial No. 732,913.

659,264.—AIR-SHIP. Charles Stanley, San Francisco, Cal., assignor to the Stanley Aerial Navigation Company, of California. Filed Aug. 7, 1899. Serial No. 726,442.

659,270.—HYDRAULIC AIR - COMPRESSING APPARATUS. William O. Webber, Brookline, Mass., assignor to Walter C. Carr, New York, N. Y. Filed Jan. 30, 1900. Serial No. 3,327.

A hydraulic air-compressing apparatus, the combination with a water-passage, of a submerged air-chamber located adjacent thereto and having a substantially unobstructed upper face, an air-inlet pipe to said chamber of less diameter than the chamber and extending at an angle thereto, to a point above the water-level whereby a free flow of water over said upper surface of the chamber is permitted, and a series of air-outlet pipes discharging into said water-passage.

A hydraulic air-compressing apparatus, the combination with a water-passage, of a submerged air-chamber located adjacent thereto, an air-inlet pipe to said chamber of less diameter than the chamber, and a series of outlet-pipes extending from said



chamber upon opposite sides from said inlet connection therewith and each of less diameter than the inlet.

A hydraulic air-compressing apparatus, the combination with a water-passage, of a submerged air-chamber located adjacent thereto, air-inlet pipes disposed at opposite sides of the center of said chamber, and a series of air-outlet pipes from said chamber located between the points of connection of said inlet-pipes.

A hydraulic air-compressing apparatus, the combination with a water-passage, of a continuous air-chamber extending laterally of the same, a series of outlet-pipes extending from said chamber toward said water-passage, and an air-inlet for said chamber.

A hydraulic air-compressing apparatus, the combination with a water-passage, of a continuous air-chamber surrounding the same, a series of outlet-pipes, a series of outlet-pipes depending from said chamber toward said water-passage, an air-inlet for said chamber, and a central frame provided with means for raising and lowering said chamber and parts carried thereby.

A hydraulic air-compressing apparatus, the combination with a water-passage, of an air-chamber surrounding the same, a series of outlet-pipes extending from said chamber toward said water-passage, an air-inlet for said chamber, a central frame provided with means for raising and lowering said chamber, and guides between the chamber and frame for determining the horizontal position of the air-outlet pipes relative to the water-passage.

A hydraulic air-compressing apparatus, an enlarged, submerged air-inlet chamber provided with downwardly-projecting air-outlet pipes on the lower part thereof, said air outlet pipes being provided with curved guides for the purpose of guiding and regulating the amount of water passing between them.

A hydraulic air-compressing apparatus, an enlarged, submerged air-inlet chamber provided with downwardly-projecting air-outlet pipes on the lower part thereof, said air-outlet pipes being provided with curved guides for the purpose of guiding and regulating the amount of water passing between them, and adjustably connected thereto.

659,418.—PNEUMATIC HAMMER. Charles K. Pickles, St. Louis, Mo., assignor of one-half to Dwight Tredway, same place. Filed Feb. 10, 1900. Serial No. 4,803.

A pneumatic hammer, a cylinder, an impact-piston, a sleeve detachably secured to the cylinder, a valve-chamber formed in one side of said sleeve and wholly independent of and parallel with the cylinder, and a pneumatically-actuated piston-valve arranged in said valve-chamber.

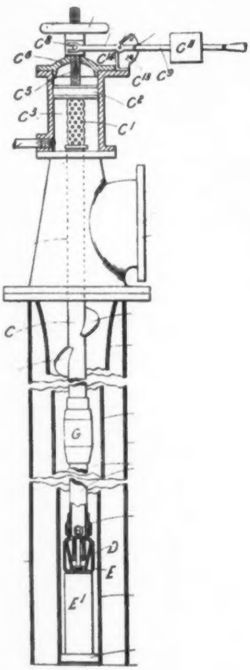
659,491. — LIQUID-RAISING APPARATUS OF THE AIR-LIFT TYPE. Joseph Price, London, England. Filed May 28, 1900. Serial No. 18,269.

A liquid-raising apparatus of the air-lift type, the combination of an air-supply pipe, a rising main for the liquid, the cross-sectional area of such main increasing from the bottom to the top, an adjustable injector air-outlet valve at the lower end of the air-supply pipe, the same comprising a downwardly-extended hollow cone, a cylindrical bell into which the cone extends, the lower end of the cone being adapted to have a seating against the bell, and a connection between the cone and bell adapted to permit of axial movement between the same, an auxiliary adjustable injector-valve between the outlet-valve and an outflow-opening in the rising main, means for imparting a spiral motion to the air in the rising main, and means for adjusting the valves.

A liquid-raising apparatus of the air-lift type, the combination of an air-supply pipe, a rising main for the liquid, the cross-sectional area of such main increasing from the bottom to the top, an adjustable injector air-outlet valve at the lower end of the air-supply pipe, an auxiliary adjustable injector-valve between the outlet-valve and an outflow-opening in the rising main, said auxiliary valve comprising a cone secured to the air-supply pipe, a surrounding sleeve having a seating for the cone, and spiral guides formed in the sleeve, and means for adjusting the main and auxiliary valves.

A liquid-raising apparatus of the air-lift type, the combination of a rising main for the liquid, the cross-sectional area of such main increasing from the bottom to the top, an air-supply pipe within the rising main, a conical outlet valve at the bot-

tom of the air-supply pipe, a cylindrical casing around such valve, guide-vanes upon the cone, a conical auxiliary outlet-valve in the air-supply pipe between the bottom outlet-valve and a liquid outflow opening in the rising main, a sleeve or casing around the conical auxiliary valve, spiral



guides within the casing, spiral vanes upon the exterior of the air-supply pipe, a cylinder in communication with the top of the air-supply pipe and with a source of pressure, a piston within the cylinder, means for balancing the weight of the piston and air-supply pipe and means for adjusting the position of such piston and pipe.

A liquid-raising apparatus of the air-lift type, the combination of a rising main for the liquid, the cross-sectional area to such main increasing from the bottom to the top, an air-supply pipe within the rising main, a conical outlet-valve at the bottom of the air-supply pipe, a cylindrical casing around such valve, guide-vanes upon the cone, a conical auxiliary outlet-valve in the air-supply pipe between the bottom outlet-valve and a liquid-outflow opening in the rising main, a sleeve or casing around the conical auxiliary valve, spiral guides within the casing, spiral vanes upon the exterior of the air-supply-pipe and means for raising and lowering the air-supply pipe.

A liquid-raising apparatus of the air-lift type, the combination of a rising main for the liquid the cross-sectional area of such main increasing from the bottom to the top, an air-supply pipe within the rising main, a conical outlet-valve at the bottom of the air-supply pipe, a cylindrical casing around such valve, guide-vanes upon the cone and means for opening and closing and adjusting the outlet-valve.

A liquid-raising apparatus of the air-lift type, the combination with an air-supply pipe, of an outlet-valve comprising a hollow cone, a sleeve or casing around the cone, a seating for the cone within the casing, spiral guides within the casing and means for raising and lowering the cone to regulate the orifice between the cone and its seating.

659,616.—RECORDING AIR PYROMETER. William H. Bristol, Hoboken, N. J., and Edgar H. Bristol, Naugatuck, Conn., assignors to the Bristol Company, Waterbury, Conn., and New York, N. Y. Filed May 24, 1900. Serial No. 17,846.

659,703.—PNEUMATIC TYPE-WRITER. Maximilian Soblik, Merxem, Belgium. Filed July 11, 1899. Serial No. 723,435.

659,730.—AIR-EXTRACTOR FOR PNEUMATIC TIRES IN CONSTRUCTION. Augustus E. Ellinwood, Akron, Ohio, assignor to the Goodyear Tire and Rubber Company, same place. Filed March 7, 1900. Serial No. 7,653.

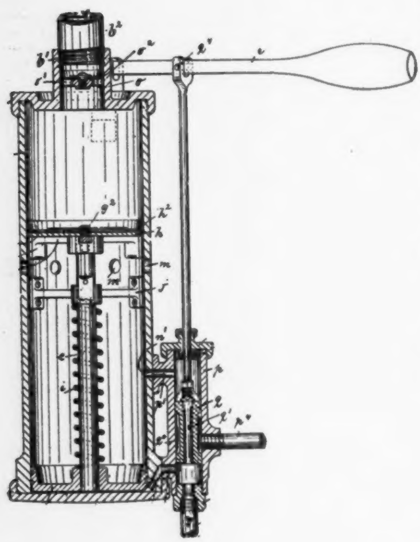
659,752.—PNEUMATIC COTTON PICKER. William H. Meyers, Sturgis, Ky., assignor of one-half to Green W. Pritchett, Corydon, Ky. Filed March 28, 1900. Serial No. 10,525.

659,832. AIR PUMP AND COMPRESSOR. Grant Sipp, Paterson, N. J. Filed May 8, 1900. Serial No. 15,898.

In a fluid-pumping, compressing or other similar apparatus, the combination, with a cylinder having a valve-controlled discharge for the compressed fluid at one end, of spaced operatively-connected pistons arranged in said cylinder, the piston adjoining the discharge end of said cylinder having a valve opening toward said discharge end of the cylinder, a supply for an actuating fluid, an exhaust for said actuating fluid, said cylinder having a port at its other end affording common communication for the supply and exhaust with said cylinder, and a valve controlling the communication between said port and the supply and exhaust, said valve being adapted to simultaneously close the supply and open the exhaust and vice versa and said cylinder having another fluid-inlet opening for the fluid to be compressed between the last-named end thereof and the valve-carrying piston.

In a fluid-pumping, compressing or other similar apparatus, the combination, with a cylinder having a valve-controlled discharge for the compressed fluid, of spaced operatively-connected pistons arranged in

said cylinder, the piston adjoining the discharge end of said cylinder, having a valve opening toward said discharge end of the cylinder, a valve-chest, a supply and an exhaust for an actuating fluid



connected to said valve-chest, said cylinder and the valve-chest having a port of communication entering the former at the other end thereof, and a valve arranged in said valve-chest and controlling the communication between said port and the supply and exhaust, said valve being adapted to simultaneously close the supply and open the exhaust and vice versa and having a port penetrating, it, said cylinder and valve-chest having another port of communication controlled by said valve, and said last-named port and the exhaust being adapted to have communication through the port of said valve, as described.

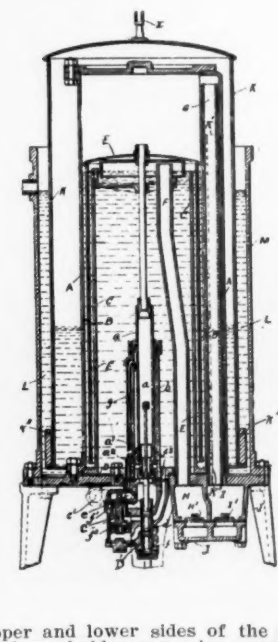
In a fluid-pumping, compressing or other similar apparatus, the combination, with a cylinder having a valve-controlled discharge for the compressed fluid at one end, of spaced operatively-connected pistons arranged in said cylinder, the piston adjoining the discharge end of said cylinder having a valve opening toward said discharge end of the cylinder, means for normally forcing said pistons away from the discharge end of said cylinder, a valve-chest, a supply for an actuating fluid and an exhaust for said actuating fluid connected to said valve-chest, said cylinder and the valve-chest having a port of communication entering the cylinder at the other end thereof, and a valve arranged in said valve-chest and controlling the communication between said port and the supply and exhaust, said valve being adapted to simultaneously close the supply and open the exhaust and vice versa and having a port penetrating it, said cylinder and valve-chest having another port of communication controlled by said valve, and said last-named port and the exhaust being adapted to have communication through the port of said valve.

660,070.—AIR-RIFLE. William J. Burrow, Plymouth, Mich., assignor to the Daisy Manufacturing Company, same place. Filed Jan. 4, 1900. Serial No. 300.

660,159.—PNEUMATIC STACKER. Clarence B. Hixson, Charles T. Hixson and Asa L. Tarrant, Holt, Okla. Filed Feb. 2, 1900. Serial No. 3,696.

660,253. APPARATUS FOR PUMPING OR COMPRESSING GAS AND AIR. James Keith, London, England. Filed Jan. 12, 1899. Serial No. 701,954.

A double-acting gas-compressing pump comprising a cylinder, a pump-plunger moving therein having gas-pipes for the inlet and discharge of the gas to and from



the upper and lower sides of the plunger, a loaded gas holder or receiver surrounding the pump plunger and cylinder, a fluid-pressure motor for operating the pump plunger,

a cock controlling the supply of fluid to said motor and a connection between said cock and loaded gas-holder.

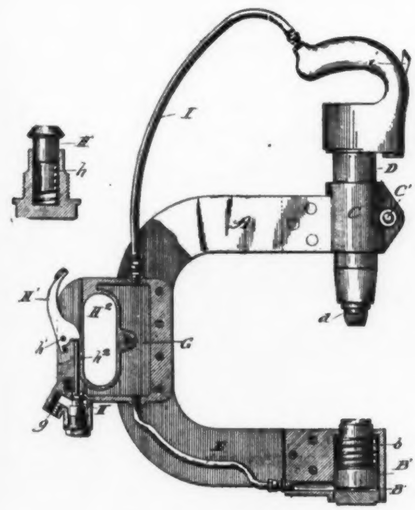
A double-acting gas and air compressing and mixing apparatus comprising a motor, a pump-plunger comprising a double cylinder, a water seal into which the double cylinder dips, means for admitting water automatically to the water seal, an open-ended cylinder, dipping into a water seal carried by the double cylinder, a pump-cylinder A, air and gas pipes leading to the separated spaces formed by the double cylinder of the pump-plunger and the open-ended cylinder, a loaded gas-receiver surrounding the pump and means for controlling the water-supply connected with the said loaded receiver.

660,466.—AIR MATTRESS OR CUSHION. Albert H. Sawtell, Malden, Mass., assignor to The Pneumatic Goods Company, Boston, Mass. Filed Dec. 7, 1899. Serial No. 739,497.

660,650.—AIR-BRAKE. Joseph E. Normand, Watertown, N. Y., assignor of one-half to Joseph R. Ellicott, Nyack, and Charles A. Ball, New York, N. Y. Filed Sept. 21, 1899. Serial No. 731,182.

660,705.—PNEUMATIC TOOL. Henry J. Kimman, Chicago, Ill. Filed Oct. 27, 1899. Serial No. 734,936.

A tool of the class described, the combination of a bifurcated frame portion provided at one end with a movable clamping-



plunger to contact the head of a rivet and the other end with means to receive and removably hold a portable pneumatic hammer.

A tool of the class described, the combination of a bifurcated frame portion provided at one end with a movable clamping-plunger adapted to contact one end of a rivet and at the other with a clamping portion adapted to receive a pneumatic hammer.

A tool of the class described, the combination of a bifurcated frame portion provided at one end with a pressure-chamber having a movable clamping-plunger therein to contact the head of a rivet and at the other end with a pneumatic hammer and a main supply-chamber adapted to contain a supply of motive fluid and connected with the clamping-plunger chamber and with the pneumatic hammer and a main throttle-valve in the inlet of such main supply-chamber adapted to open and close to the inlet of each supply-chamber.

A tool of the class described, a substantially C-shaped frame portion provided at one end with a pressure-chamber having a clamping counterbalancing ; reciprocating plunger therein and at the other end with a clamp adapted to removably hold a portable pneumatic hammer, a main inlet chamber G connected with the pressure-chamber of the heading-plunger and arranged to be connected with the portable pneumatic hammer, and a main throttle-valve to control the supply of motive fluid to such inlet-chamber.

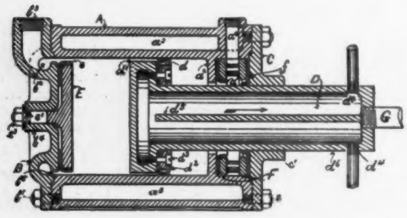
660,793.—SINGLE-CYLINDER COMPOUND COMPRESSOR. Thos. Grant, New York, N. Y., assignor of one-half to Hartwig A. Cohen, Dalamar, Nev. Filed June 12, 1899. Serial No. 720,310.

In the cylinder of a compressor, the combination with an annular cup-shaped valve located with its turned-up edge at or near the cylindrical surface of the cylinder, of a retaining plate E, facing the piston of the cylinder and bearing against the base of said valve, which in turn bears against the end of the cylinder, a spindle e' terminating the central portion of the retaining-plate E, and turned down to form a smaller portion e^2, for receiving a fastening nut e^3, and a back cylinder-head B, having a boss b^4, through which passes said spindle e'.

A compressor consisting of the combination of a single cylinder of uniform internal diameter, having an inlet-valve at one end and an outlet-valve at the other end, a plunger whose diameter is less than said internal diameter and having an enlarged head whose forward compressing-surface faces the inlet-valve and is equal to the cross-sectional internal area of the cylinder, and whose rear compressing-surface faces the outlet-valve and is substantially equal to the difference of the cross-sectional cylinder area and the cross-sectional plunger area, and a valve carried by the enlarged head, between the spaces of the cylinder divided off by the said head, and forming an inlet from the larger area space to the smaller space.

In a compressor, the combination with the front cylinder-head thereof, of an internal circular flange a^2, a piston passing within said flange and through the front cylinder-head C, a cage consisting of two

parallel rings f', separated by separating-pieces f^2, and bearing upon the inner surface of said cylinder and located between said flange a^2, and said cylinder-head C,



and packing-ring f, bearing upon said piston and located between said cage and said head, a cup-shaped valve a', having its base between said cage and said flange a^2, and having its edges between said cage and said piston to form a valve between the interior of the cylinder and the space between the rings f', the cylinder A, of the compressor having an outlet-port a^4, which opens into the space between the rings f.

660,857.—PNEUMATIC TOOL. Herman G. Kotten, Englewood, N. J. Filed Jan. 11, 1900. Serial No. 1,098.

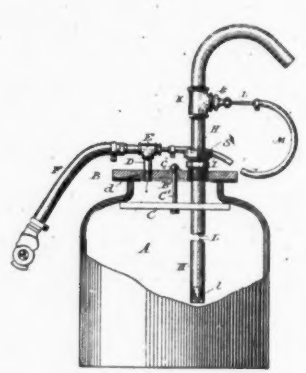
A pneumatic tool, a cylinder, a solid hammer therein, having an unbroken periphery, but provided with longitudinally-extending recesses on either side thereof, a groove in the inner periphery of said cylindr always in communication with said recesses, an inlet-port in said cylinder leading to said groove, other grooves in the inner periphery of said cylinder on either side of said first-mentioned groove, and ports and passages for admititng and exhausting the motive fluid from either end of said cylinder.

660,916. — AIR-GAS APPARATUS. Caspar W. Miller, Wallingford, Pa. Filed June 7, 1899. Serial No. 719,681.

660,946. — APPARATUS FOR PUMPING WATER, SAND, ETC.. Thomas Butler, Cleburne, Tex. Filed March 28, 1900. Serial No. 10,503.

The combination, substantially as set forth, of an air-tight vessel, a cap fitting air-tight to an opening in the upper end thereof and removably connected therewith, a discharge-pipe carried by the cap extending through it down into the vessel, an entrance for compressed air in the cap opening into the vessel above the open lower end of the discharge-pipe and above the material in the vessel, a pipe supplying compressed air to the vessel through said entrance-opening, a relatively small pipe extending down through the discharge pipe and discharging compressed air upward in the discharge-pipe near its lower end, and connections between the upper end of said relatively small pipe and the main compressed-air-supply pipe, the organization being such that compressed air is forced into the vessel upon the surface of the material to cause it to enter the lower end of the discharge-pipe while compressed air acting as an ejector enters the discharge-pipe at its lower end and forces the material upward therein.

The combination, substantially as set forth, of an air-tight vessel, a cap fitting air-tight to an opening therein and removably connected therewith, a discharge-pipe extending through a stuffing-box in the cap in which it is free to move vertically and to turn about its axis, a compressed-air pipe opening into the vessel through the cap, a relatively small pipe contained in the discharge-pipe and extending through the cap down into the vessel and discharging upward in the discharge-



pipe near the lower end thereof, and a flexible pipe connecting the main compressed-air-supply pipe with the upper end of the relatively small pipe contained in the discharge-pipe.

660,961.—PNEUMATIC HAMMER FOR ROCK DRILLS. William G. Jones and William O. Pierce, Penmaen-Mawr, England, assignors of one-third to William Maine Treglown, London, England. Filed July 23, 1900. Serial No. 24,552.

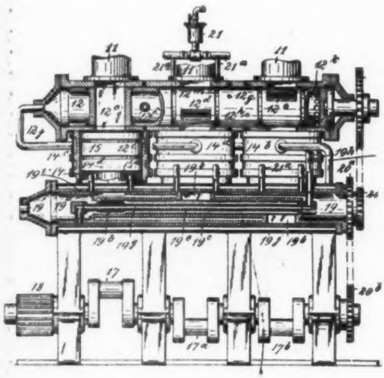
Pneumatic hammers and other automatic percussive tools, means for effecting the rotation of the cutting-tool, consisting of a motor, a toothed wheel slidably and directly mounted upon the cutting tool, and gear between the motor and the toothed wheel.

660,997.—COOLING MEANS FOR MOTOR-COMPRESSORS. John T. Nicolson, Manchester, England. Filed Sept. 12, 1900. Serial No. 29,759.

An air compressor, a rotary compressor-valve having an annular chamber in communication with an end air admission, a port in the outer wall corresponding with a cylinder-port, a central cavity communicat-

ing with the delivery-outlet, said cavity having also a port corresponding with the cylinder-port and a tube forming part of a water-circulating system.

A jacketed rotary valve for an air-compressor, an axial tube surrounded by a



space through which the compressed air is delivered, a branch of said tube at one end opening through the surface of the valve and communicating with a water-admission port, and a second branch at the opposite end of the tube also opening through the surface of the valve and communicating through a port with the water-jacket.

UNITED STATES COMMISSION TO THE PARIS EXPOSITION OF 1900.

PARIS OFFICES, Aug. 31st, 1900.

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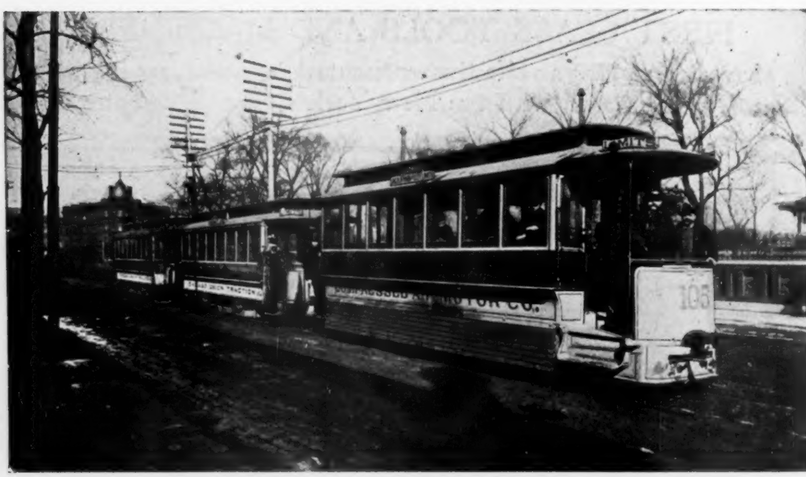

The above cut is of a 28 foot Compressed Air Motor Car hauling two trail cars in Chicago.

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